# Update of a Pest Management Evaluation for the California Tomato Industry
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**John LeBoeuf, Dr. W. Thomas Lanini, Edward Beckman and Charles Rivara**
**for the**
**California Tomato Commission and the California Tomato Research Institute**

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Mr. John LeBoeuf, AgriDataSensing, Inc.
8398 North Ninth Street, Fresno, CA 93720
(559) 431-2360 AgriDataSensing@netscape.net

Mr. Ed Beckman, President and CEO
California Tomato Commission
1625 East Shaw Avenue, Suite 122, Fresno, CA 93710
(559) 230-0116 Beckman@tomato.org

Dr. W. Thomas Lanini, Extension Weed Ecologist
University of California, Davis, CA 95616
(530) 752-4476 wtlanini@ucdavis.edu

Mr. Charles Rivara, Director
California Tomato Research Institute, Inc.
18650 East Lone Tree Road, Escalon, CA 95320
(209) 838-1594 chuck@tomatonet.org

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Dr. Nita Davidson, California Department of Pesticide Regulation
830 K Street, Sacramento, CA 95814
(916) 324-4272 ndavidson@cdpr.ca.gov

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# Abstract

This document represents a pest management evaluation of various practices and alternatives currently utilized by the California fresh market and processing tomato industries.

Information relating to the importance of pesticides used in California was reviewed for the two distinct and separate industries, which have formed the "Tomato Alliance" for the purpose of this report. The evaluation was submitted as a requirement of the Pest Management Alliance Program of the Department of Pesticide Regulation, as a joint effort of the California Tomato Commission and the California Tomato Research Institute, Inc.

Members of the tomato industry, representing growers, packers, shippers, and pest control consultants, were interviewed on current information regarding pest control problems of significant concern to the various tomato growing regions. Their voluntary input provided an important perspective on pesticides and alternatives utilized in the on-going integrated pest management practices employed throughout the crop growing cycle. As a result of their comments, the Pest Management Evaluation focused on those pests that have the most significant economic impact on the industry. From this survey, it was determined that disease presented the greatest risk to the fresh and processed tomato industries. In addition, the greatest opportunity for risk reduction was found to be in conjunction with the adoption of new disease forecasting technology. Several insect species also are of major concern to tomato growers. Field monitoring techniques based on pheromone trapping could be enhanced with the implementation of new and advancing studies involving ecological distribution of pests and phenology models.

The report concluded with a listing of the most often used chemical inputs and non-chemical practices used in tomato production.

# CALIFORNIA TOMATO PEST MANAGEMENT EVALUATION

## PRODUCTION FACTS

- California ranks first in the nation in processing tomato production and second, behind Florida, in production of fresh market tomatoes.
- In the U.S., approximately 93% of the processing tomatoes and 27% of fresh market tomatoes are grown in California.
- Processing tomatoes were grown in 1998 on approximately 282,000 acres in California, with about 280,000 acres harvested with a cash value of $499,775,000. Fresh market tomatoes were grown on approximately 32,000 acres in California, with 32,000 acres harvested with a cash value of $283,392,000.
- The average yield in 1998 for processing tomatoes was 31.76 tons per acre while the average yield for fresh market tomatoes was 13.5 tons per acre.

## PRODUCTION REGIONS

The main tomato-growing areas in California are shown in Figure 1 on page 2. Area I grows about 60% of the state's processing tomatoes, centered in Yolo County. Planting of processing tomatoes extends from January to mid-June and harvest from July to early October. About 40% of fresh market tomatoes are produced in this area—mostly San Joaquin, Stanislaus and Merced counties. Nearly all the fresh market tomatoes are from bush varieties. Planting of fresh market tomatoes is from February to June with harvest from mid-July to late October.

Area II, the San Joaquin Valley south of Merced County produces 35 to 40% of the processing tomatoes, planting from January to early April and harvesting from June to August. This area also produces about 30% of the fresh market tomatoes. Cherry tomatoes are grown in some areas of Fresno southward. Planting fresh market tomatoes is mostly from February to March and harvest from mid-June into September.

Area III, the Central Coast, produces about 5% of the state's fresh market tomatoes. The planting period is from March to May and harvest from August to October.

Area IV, the South Coastal area, also grows about 20% 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.

Area V, 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.

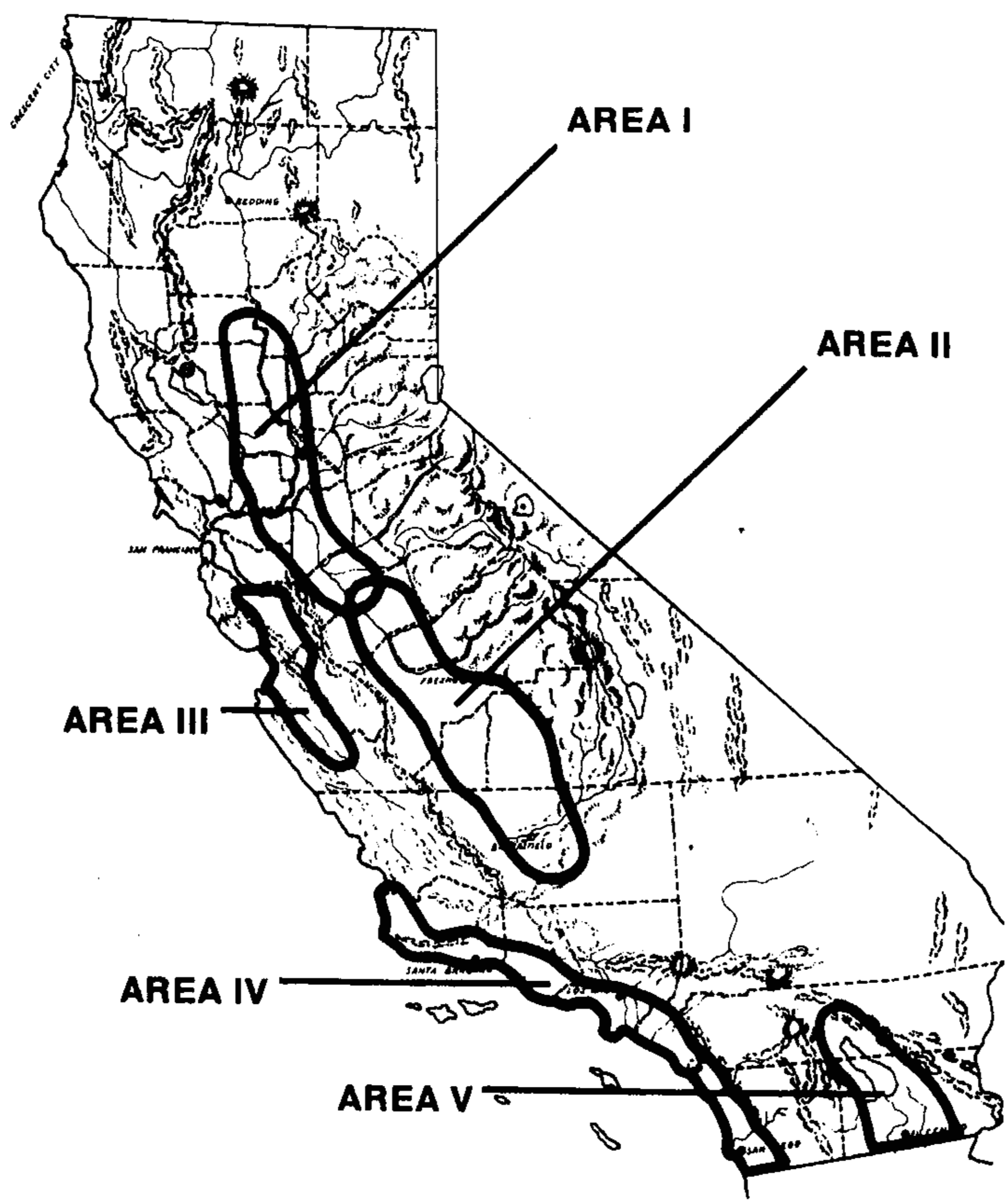


**Figure 1.** Major tomato producing areas in California.

## CULTURAL PRACTICES

Tomatoes have the most value when they arrive to the market during a certain time interval. Microclimates and projected market conditions further influence fresh market cropping patterns with planting schedules set by shippers for the growers they contract with. Processing tomatoes are generally delivered to market within a two-week period, within that time period set by the processor. In order to meet this commitment, growers must plan their planting time carefully.

**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 processing tomatoes are direct seeded. Tomatoes are direct seeded in either one or two rows per bed, with single rows being the most common. Plants in double rows can more effectively fill gaps created by planting problems. 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).

**Transplanting** provides the tomato plants a head start on weeds and reduces stand establishment problems. About 90% of the fresh market tomatoes are transplanted. However, transplants have 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. Fresh market tomatoes have been successfully grown on poles across rolling terrain in Area IV.

**Irrigation** is used for all California tomatoes. Furrow irrigation is the most commonly used irrigation method 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 is often used to germinate a direct seeded crop. Sprinkler irrigation is also needed for incorporation of some herbicides, such as Shadeout (rimsulfuron). 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 fertilization resulting in higher yield. Subsurface drip irrigation is used on a small portion of the drip-irrigated tomatoes. By maintaining a dry surface during the summer growing season, weed emergence is reduced and water use is further reduced.

**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), while processing tomatoes receive an average of a little less than two insecticide applications per year (Appendix-Table 2). The primary pests targeted by these treatments include tomato fruitworm, armyworms, mites, aphids, stink bugs, whiteflies, flea beetles, and leafhoppers.

**Herbicides** are used for weed control on 99% of the tomatoes grown in California (Appendix-Tables 3&4). 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.

**Fungicides** are used on approximately 80% of the fresh market tomatoes grown in California and about 60% of the processing tomatoes. Fresh market tomatoes generally receive 1.5 to 2 fungicide treatments per year (Appendix-Table 5), with the majority applied as foliar treatments. Fungicides are applied 1 to 1.5 times in processing tomatoes (Appendix-Table 6), with most applications being foliar. The major disease organisms targeted by these treatments include *Phytophthora* root rot, black mold rot, bacterial speck, bacterial spot, early and late blight, and powdery mildew.

The Plant growth regulator Ethephon (Ethrel) is sometimes used as a ripening agent on fresh market tomatoes. Information on acreage treated with Ethephon (10) can be found in Table 3 in the appendix.

## INSECT and MITE PESTS

Numerous insect and mite pests attack tomatoes in all of the growing regions of the state and in most seasons can occur at damaging levels. 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 depends on production region and type of tomato crop—fresh market or processing.

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 major pest problems in fresh market and processing tomato production.

Information on total pounds of pesticides applied to tomatoes can be found in the 1998 Annual Pesticide Use Report Indexed by Commodity published by the Department of Pesticide Regulation. Caution must be used when looking at these data sets as "The summary information in this annual report cannot be used to determine the total number of acres of a crop to which pesticides were applied during the year". It also isn't readily apparent how many acres were treated multiple times nor how many acres of a crop were not treated with any one pesticide.

## Fruit and Foliage Pests

**Stink Bugs Consperse 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 and also to tomatoes used for whole peel processing. 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). Stink bugs are considered by many PCAs and growers as the hardest insect species to control when populations threaten a tomato crop.

## Controls

Treatment for stink bugs is generally more likely in fresh market tomato production 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 Control

**Endosulfan** (Thiodan)—2 days preharvest interval (PHI). Application rates vary from 1 to 1.3 quarts per acre for the 3 EC formulation or 1.5 to 2 lbs. per acre for the 50 WP formulation. 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 especially impacts Merced, San Joaquin, and Sacramento region. Maximum number of three applications per year depends on rate used with 6 lb. per year maximum for the 50WP formulation and 4 quart maximum for the 3EC formulation.

**Dimethoate** (Dimethoate 400 or E267)—7 days PHI. Application rates vary from 1.5 pint per acre for the E267 formulation to 1 pint per acre for the 400 formulation. 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)— 7 days PHI depending upon manufacturer. Special Local Need #CA-780163. 1.5 to 2 pints per acre application rate. 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.

**Imidacloprid** (Admire 2)—21 days PHI. 16 to 24 ounce per acre application rate. 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. 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 Control

**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 Control

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.

## Controls

### Chemical Control

**Methomyl** (Lannate)—1 day PHI but 2-day field reentry for workers. Application rate is from 0.5 to 1 pound per 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.

***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. 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)—1 day PHI. Application rates vary from 5.8 to 9.6 fluid ounces per 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)—1 day PHI. Label rates of 3-6 oz. Product per acre. This material was recently registered in 1998 and application patterns have yet to be established. Early reports are variable as can be expected from a product that has had little commercial development time.

### Biological Control

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. Active parasitism can be monitored by looking for black, parasitized fruitworm 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 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.

### 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. Tables 7 & 8 in the appendix list the non-chemical control practices used in tomato production with estimates of acreage involved.

## Controls

### Chemical Control

**Methomyl** (Lannate)— 1 day PHI but 2 day field reentry for workers. Application rate is from 0.5 to 1 pound per acre. It has been suggested that methomyl applications have caused *Liriomyza* leafminer 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)—1 day PHI. Application rates vary from 5.8 to 9.6 fluid ounces per 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.

**Spinosad** (Success)—1 day PHI. Label rates of 4-8 ounces of product per acre. This material was recently registered in 1998 and application patterns have yet to be established. Early reports are variable as can be expected from a product that has had little commercial development time.

### Beet Armyworm, *Spodoptera exigua*

Both growers and PCAs reported armyworm 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 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. Releases of beneficial insects and parasites for lepidopterous larval control has been very limited in scope and success.

## Controls

### Chemical Control

**Methomyl** (Lannate)—1 day PHI but 2-day field reentry for workers. Application rate is from 0.5 to 1 pound per acre. It has been suggested that methomyl applications have caused *Liriomyza* leafminer 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.

***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. Often 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)—1 day PHI. Application rates vary from 5.8 to 9.6 fluid ounces per 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)—1 day PHI. Label rates of 4-8 oz. Product per acre. This material was recently registered in 1998 and application patterns have yet to be established. Early reports are variable as can be expected from a product that has had little commercial development time.

### Biological Control

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.

### 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 monitoring of the pest though there is an effective pheromone attractant available for use to monitor male moth flight activity. Insect degree day data can be used in phenology models to alert PCAs and field personnel when a potential pest problem has been detected so that field monitoring activities can be implemented. Current research activities have been aimed at collecting regional data to validate the computer models. The chemical and biological control alternatives are the same as those previously listed for beet armyworm.

### 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 (1.5mm). 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 fresh 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 the detrimental populations usually don't arise until later in the summer after the spring tomato crop has been harvested.

### Chemical Control

**Endosulfan** (Thiodan)—2 days preharvest interval (PHI). Application rates vary from 1 to 1.3 quarts per acre for the 3 EC formulation or 1.5 to 2 lbs. per acre for the 50 WP formulation. This material is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways. It also has restrictions regarding its use when irrigation water is running in the field. Maximum number of three applications per year depends on rate used with 6 lb. per year maximum for the 50WP formulation and 4 quart maximum for the 3EC formulation. 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)—7 days PHI. Application rates vary from 1.5 pint per acre for the E267 formulation to 1 pint per acre for the 400 formulation. 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.

**Methamidophos** (Monitor 4)— 7 days PHI depending upon manufacturer. 1.5 to 2 pints per acre application rate. Pest Control Advisers report excellent results with this material. The insecticide requires extremely careful handling as it has a danger poison label as a category 1 material.

**Imidacloprid** (Admire 2)—21 days PHI. 16 to 24 ounce per acre application rate. Systemic material works very well as a preventive for low populations. May be applied in drip irrigation. Imidacloprid is a category 3 material with a caution label. It commonly offers six to seven week control of all sucking insects when the material is properly applied, that is when the soil is not dry but wet enough to allow roots to pick up the material and translocate the compound.

**Insecticidal Soap** (M-Pede)—0 days PHI. 2.5 oz./gallon of water. 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)** —A systemic carbamate used postplant. This material can be injected into drip irrigation systems. Oxamyl is a category 1 material with a danger poison label.

**Neem Oil (Trilogy)** —Section 3 regular registration for the clarified hydrophobic extract 70% Neem oil with a category 3 caution label. Applied by ground rigs for better coverage, it also controls thrips, mites, leafhoppers, and fungi.

## Foliage Pests

### Potato Aphid, *Macrosiphum euphorbiae*

The potato aphid represents a species that has been previously viewed as a minor pest that has been showing upon 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.

### 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)—7 days PHI. Application rates vary from 1.5 pint per acre for the E267 formulation to 1 pint per acre for the 400 formulation. Severe hazards to bees, so caution must be exercised if bee hives are placed in the area. Secondary pests such as leafminer are often associated with successive treatments of dimethoate.

**Imidacloprid** (Admire 2)—21 day PHI. 16 to 24 ounce per acre application rate. Systemic material works very well as a preventive. The material is much more expensive than dimethoate, but few secondary pest problems arise. May be applied in drip irrigation.

**Endosulfan** (Thiodan)—2 days PHI. Application rates vary from 1 to 1.3 quarts per acre for the 3 EC formulation or 1.5 to 2 lbs. per acre for the 50 WP formulation. The material is seldom used since a 300 foot buffer restriction applies to applications to fields that have drainage into waterways. This especially impacts the Merced, San Joaquin, and Sacramento growing regions. Maximum number of 3 applications per year depends on rate used with 6 lb. per year maximum for the 50WP formulation and 4 quart maximum for the 3EC formulation.

**Diazinon** (Diazinon AG500)—1 day PHI. 0.5 pint per acre application rate. 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. 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.

### Hornworms, Manduca quinquemaculata

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

### 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)—7 days PHI. Application rates vary from 0.16 to 0.55 lb. a.i./ac. In 1997, 25.1 percent of the acres were treated an average of one time with dimethoate at a median application rate of 0.47 lb. a.i./ac. 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 application are needed for adequate control.

**Oxamyl** (Vydate)—A systemic carbamate used postplant - if drip irrigation is used, this material can be injected into the irrigation system. Application rates vary from 0.49 to 1.05 lb. a.i./ac. with a median application rate of 0.52 lb. a.i./ac. In 1997, 5.28 percent of the acres were treated an average of one time. 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)—7 day PHI. 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. Applications are made at a median rate of 0.01 lb. a.i./ac. In 1997, 3.96 percent of the acres were treated an average of one time.

**Azinphos methyl** (Guthion)—14 day PHI. Application rates vary from 0.5 to 1.0 lb. a.i./ac, with a median application rate of 0.75 lb. a.i./ac. In 1997, 1.11 percent of the acres were treated an average of two times. 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**—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 at the rate of 0.12 lb. a.i./ac., an average of one time per season. In 1997, 2.52 percent of the acres were treated.

## 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. Multiple preventive applications are usually required if favorable environmental conditions occur. Application rates vary with the manufacturer but 40 to 50 pounds per acre are common. 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. The application rate varies from 0.38 to 0.76 lb. a.i./ac, with a median application rate of 0.75 lb. a.i./ac. In 1997, 1 percent of the acres were treated an average of one time. Dicofol is not labeled for chemigation through irrigation systems.

**Abamectin** (Agri-mek 0.15 EC)—7 day PHI. 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. Applications are made at a median rate of 0.01 lb. a.i./ac. In 1997, 3.96 percent of the acres were treated an average of one time.

## 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. Application rates vary from 0.5 to 1.0 lb. a.i./ac, with a median application rate of 0.75 lb. a.i./ac. In 1997, 1.11 percent of the acres were treated an average of two times. 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)—2 days preharvest interval (PHI). Application rates vary from 0.58 to 1.03 lb. a.i./ac., with a median application rate of 0.99 lbs. a.i./ac. 1.97 percent of the acres were treated in 1997 an average of one time. 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)**—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. Applied at an median application rate of 1.0 lb. a.i./ac, usually once per season. In 1997, 9.22 percent of the acres were treated.

## 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)**—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. Applied at an median application rate of 1.0 lb. a.i./ac, usually once per season. In 1997, 9.22 percent of the acres were treated.

**Esfenvalerate** (Asana XL)—1 day PHI. Application rates vary 0.02 to 0.05 lb. a.i./ac with a median application rate of 0.04 lb. a.i./ac. In 1997, 48 percent of the acres were treated an average of one time. 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. Applied at the rate of 0.13 to 0.2 lb. a.i./ac, with a median application rate of 0.19 lb. a.i./ac. by ground or aerial applicators. In 1997, 7.5 percent of the acres were treated an average of 1 time.

## WEEDS

The most common weeds infesting tomatoes in California are listed in Table 9 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. Rimsulfuron, recently registered, is intended to provide good preemergent and postplant control. Growers and advisors are still establishing the use patterns.

**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. However, rimsulfuron is in the family of herbicides that inhibit acetolactate synthase (ALS) which is also known as aceto-hydroxyacid synthase (AHAS), a key enzyme in the biosynthesis of certain amino acids in the plant. Weeds have developed resistance to this family of herbicides very rapidly in other crops, and thus a herbicide resistance management program has been initiated.

**Alternative weed control practices** with estimated acreage involved in tomato production are listed in the appendix in Tables 10 & 11. 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, but seldom used in processing 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.

Markets or delivery contracts established long before the crop is planted 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. Locally, however, some processing tomato buyers have initiated programs to reduce the amount of pesticides used in the production of fruit they purchase from growers. This has not impacted growers at present but may do so in the future.

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. Also in the appendix is Table 3, which shows the herbicide use on processing tomatoes.

**FALL BED (application before weeds emerge)**

**Napropamide** ( Devrinol 2EC, 50DF) —Rate is dependent upon soil type with 2-4 quarts per acre for 2EC formulation and 2-4 pound rate for 50DF formulation. 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)—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. Usage rates are dependent upon soil types and formulations. This material is used for the control of annual broadleaves.

**Oxyfluorfen** (Goal 2X)—1-2 pint per acre rate. 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. Ten-month plant back restriction for crops not on the label.

**FALL BED (application after weeds emerge)**

**Paraquat** (Gramoxone Extra 2.5S)—30 days PHI. 2-3 pints per acre rate. 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)—3 day preplant restriction. 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)—14 day preplant interval between application and planting date. Rates vary with bandwidth sprayed on beds or broadcast application.

**Pebulate** (Tillam 6EC)—2.66-4 quart per acre rate dependent upon soil type as clay soils require the higher rate. Pebulate is used for the control of yellow nutsedge and hairy nightshade along with most annual broadleaves and grasses.

**Napropamide** (Devrinol 2EC, 50DF)—Rate is dependent upon soil type with 2-4 quarts per acre for 2EC formulation and 2-4 pound rate for 50DF formulation. 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)—0.8-1.6 pints per acre rate is dependent upon soil type with the lower rate used on coarse, sandy soils. 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)—30 days PHI. 1.5 pints per acre rate, which can be applied up to three times per, season. Crop oil concentrate at 1 quart per acre needs to be used with the herbicide for control of annual and perennial grasses

**Metribuzin** (Sencor 4F, DF and Lexone 75DF)—7 days 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. Usage rates are dependent upon soil types and formulations. This material is used for the control of annual broadleaves, especially black nightshade. Metribuzin should be applied when tomatoes are in the 6-true leaf stage as long as environmental conditions are favorable to avoid plant injury associated with cool and wet weather.

**LAYBY (before weeds emerge)**

**Trifluralin** (Treflan 5EC, Trilin 5EC)—0.8-1.6 pints per acre rate is dependent upon soil type with the lower rate used on coarse, sandy soils. This herbicide is applied as a directed spray to the soil between rows or as a shielded spray to avoid spraying over the tops of plants. Some yield loss could be expected from plants sprayed with the material . The herbicide must be incorporated into the top several inches of soil. It is used for control of annual grasses and broadleaves.

**EPTC** (Eptam 7EC)—21 days PHI. 3.5 pints per acre rate. This herbicide is applied as a directed spray and immediately incorporated into the soil when plants are 3-4 inches tall. Application must be kept at least two inches away from the crop row to avoid plant injury. 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)—8 days PHI. 2.66-4 quarts per acre rate dependent upon soil type as clay soils require the higher rate. Pebulate is used for the control of yellow nutsedge and hairy nightshade along with most annual broadleaves and grasses. Application is made as a directed spray and soil incorporated.

## 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)— 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 that varies from 0.36 to 1.55 lb. a.i./ac, with a median application rate of 0.62 lb.

a.i./ac. In 1997, 3.41 percent of the acres were treated an average of one time. 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.

## 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 and processing tomato production. Nonchemical control practices utilized in tomato production are identified in Tables 12 & 13 found in the appendix.

### 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 sunburnt fruit.

## Controls

### Chemical Control

**Sulfur**, Dusting or Wettable Sulfur—12 hour Field Reentry with 0 days PHI. Multiple preventive applications are usually required if favorable environmental conditions occur. Application rates vary with the manufacturer but 20 to 40 pounds per acre are common. Aerial operators make most applications.

**Azoxystrobin** (Quadris)—7 day PHI. Recently registered for use on powdery mildew. Initial grower experience, indicates control poorer than myclobutanol (Rally - Section 18 from 1994-97, not renewed in 1998).

### Cultural Control

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

### 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(Solanacea). 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 been recently focused upon site-specific information from weather stations placed in tomato fields as Growers and PCAs have reported that the California Irrigation Management Information System (CIMIS) weather stations report information that is too generic for a region.

## Controls

### Chemical Control

**Chlorothalonil** (Bravo 500, 720)—0 days PHI. Application rate is 2-3 pints per acre for the 500 formulation and 1.5-2 pints for the 720 formulation. 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)—5 days PHI. Application rate varies by formulation with range from 1.2 to 2 pounds per acre. 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)—14 days PHI. Application rate is 2 pounds per acre. 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)—5 days PHI. Application rate is 2.5 pounds per acre. Used as a rotational material with the other registered materials.

**Azoxystrobin** (Quadris)—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). Used as a foliar spray in a preventive program.

**Propamocarb hydrochloride/chlorothalonil** (Tattoo C)—7 day PHI. Section 18 use in 1998. 2.3 pints per acre rate. 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.

### Cultural Control

The pathogen is highly dependent on free water, allowing for some management by irrigation reduction. Growers are unable to greatly reduce irrigation 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.

Disease forecasting with on-site weather stations offers site-specific information on important parameters such as relative humidity, air temperature, leaf wetness, and rainfall. Disease severity ratings are being compiled when numerous stations are networked to provide regional information along with individual field conditions. Implementation of a more extensive weather station system would increase the value of information for timing of fungicide applications.

### Black Mold, *Alternaria alternata*

Black mold is a disease of ripe tomato fruit that appears in the field after rain or 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.

## Controls

### Chemical Control

**Azoxystrobin** (Quadris)—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. Used as a foliar spray in a preventive program.

**Chlorothalonil** (Bravo 500, 720)—0 days PHI. Application rate is 2-3 pints per acre for the 500 formulation and 1.5-2 pints for the 720 formulation. 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)—5 days PHI. Application rate varies by formulation with range from 1.2 to 2 pounds per acre. Used as a foliar spray in a preventive program in rotation with chlorothalonil.

### Cultural Control

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.

### <u>Controls</u>

### Chemical Control

**Copper hydroxide** (50% Copper equivalent)—0 days PHI. Application rate is 2 pounds per 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 Control

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.

## Other Pests

### 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 Control

**Metam Sodium** (Soil Prep, Vapam, Sectagon II)—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.

**Oxamyl** (Vydate)—1 day PHI. A carbamate used as a preplant material or postplant if drip irrigation is used. Oxamyl can be shank injected along both sides of the plant row at planting to get the material into the plant as soon as possible as galls can be formed within a month of planting. 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 Control

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 Control

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

## Vertebrates

### 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 Control

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 Control

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 Control

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.

### <u>Control</u>

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.

## CHALLENGES TO IMPLEMENTING CHANGE

California's tomato industry has an established track record in the adoption of reduced risk technology for the control of pests and disease that is threatened by market pressures. The economic return to the grower has declined, the result of increased global competition, therefore, growers are giving greater attention to the costs of control based upon little or no revenue from the crop. As traditional broad-spectrum controls are replaced by newer controls, the percentage of production expense related to chemical control has increased, thus, growers look to incorporate more technologically advanced control measures, both to improve yield and fruit quality, and to address rising production costs. As a result, traditional chemical spray programs have been found to be less effective, and more expensive than newly developed IPM-based programs in fresh market tomatoes (Trumble, 1999). This trend is projected to continue and will serve to further the adoption of reduced risk controls.

Consumer attention to food safety issues remains high, with significant pressure upon the fresh market industry to provide extensive documentation or pesticide testing, as a condition of sale. Most recently, Safeway Stores required third party testing of all produce. Many buyers are demanding quality assurance programs; thus, growers are competing for sales based upon their use of reduced risk production practices.

As a result of the changing competitive landscape for the tomato industry, growers must continue to further their adoption of IPM-based controls. Because of the declining profitability for the grower, unless the new technology is economically advantageous, it is projected that the number of tomato growers in California will decline.

At the grower level, the adoption of reduced risk controls is further limited by increasing concerns over liability. In Southern California, fresh tomato acreage is adjacent to urban developments, primarily, single-family housing. Growers note that any chemical usage, even that of insecticidal soaps, generates possible litigation by nearby homeowners.

In another example of liability, pest control advisors are increasingly demanding that growers follow their recommendations without deviation, as a condition of consultation services. Thus, growers are becoming removed from the day to day pest management of their acreage.

Further serving to challenge the adoption of new technology is the decline in the University of California Farm Advisor network. The number of active farm advisors, with extensive knowledge in tomato production practices has declined, or is best characterized as a specialist in either fresh or processing tomatoes, not both. As a result, there is less interaction between growers and farm advisors, who for years, served in an educational role to the industry.

The greatest concern of the industry is on the evolving pest and disease complex within the State. In the fresh market industry, production in the Salinas Valley has declined from more than 125 million pounds to 35 million pounds, the result of widespread late blight. The late blight problem is expanding throughout the San Joaquin Valley as well. Tomato acreage in Huron, in Western Fresno County, has also declined, the result of multiple virus problems; in Tulare County, the last commercial production was in 1997, and was discontinued as a result of virus.

## INNOVATION

The most promising technology to the California tomato industry is the adoption of disease forecasting models for black mold, late blight, and powdery mildew. The California Tomato Research Institute continues to validate models for black mold through their existing network of remote weather stations. The California Tomato Commission funded the development of a powdery mildew forecasting model through Dr. Mike Davis, University of California, Davis. Now in validation, the model will be tested throughout California for a third year. The Commission has also invested for three years in the validation of established models for late blight.

The use of disease forecasting technology alerts the grower to recognize conditions that favor disease development, and promotes the use of chemical controls only when conditions warrant their use. Such programs promote preventative spray programs during such weather conditions, which have been found to be less intensive than seeking control in a field where the disease has already been established. In addition, the grower learns to recognize favorable conditions for disease development, and becomes more proficient in scouting for the disease.

The use of remote weather stations should also provide industry with the means to incorporate the use of degree-day models in pest management practices. Although some degree-day models exist, this is a practice that is unproven in California tomato production. Efforts to advance pheromone-based monitoring of stink bugs are also being coordinated to bring valuable information to the fresh market and processing tomato industries.

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**Key Contacts:**

**Fresh Market Tomatoes**
**Mr. John LeBoeuf**
**AgriDataSensing, Inc.**
**(559) 431-2360**

**Processing Tomatoes**
**Mr. Chuck Rivara**
**California Tomato Research Institute, Inc.**
**(209) 838-1594**

# Appendix

## List of tables

# EXHIBITS

| 1. Insecticides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes | | | | | | | |
|---|---|---|---|---|---|---|---|
| Insecticide | Treatment rate (lb ai/A) | Timing of treatment | Number of applications | Target pest | Acreage treated | | Pesticide Use (lb ai) |
| | | | | | % of crop | acres | |
| ABAMECTIN | 0.01 | F | 2. | LEAFMINERS | 30. | 11394. | 228. |
| AZINPHOSMETHYL | 0.71 | F | 2. | ARMYWORM, FRUITWORMS, PINWORMS | 15. | 5697. | 8090. |
| BT | 0.06 | F | 1.5 | BEET ARMYWORM, CABBAGE LOOPER, TOMATO FRUITWORM | 15. | 5697. | 513. |
| CARBARYL | 1.07 | F | 2.3 | BEET ARMYWORM, CABBAGE LOOPER, TOMATO FRUITWORM | 13. | 4937.4 | 12151 |
| DIAZINON | 0.48 | F | 6.7 | BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS | 6. | 2278.8 | 7329. |
| DIMETHOATE | 0.44 | F | 2.2 | BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS | 27. | 10254.6 | 9926. |
| ENDOSULFAN | 0.56 | F | 2. | APHIDS, FLEABEETLES, WHITEFLIES | 20. | 7596. | 8508. |
| ESFENVALERATE | 0.04 | F | 2. | BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, HORNWORM, CABBAGE LOOPER | 57. | 21648.6 | 1732. |
| METHAMIDOPHOS | 0.86 | F | 1.5 | BEET ARMYWORM, TOMATO FRUITWORM, STINK BUGS, LEAFMINER, APHIDS | 47. | 17850.6 | 23027. |
| METHOMYL | 0.61 | F | 1.8 | BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, APHIDS | 47. | 17850.6 | 19600. |
| OXAMYL | 1. | F | 3. | LEAFMINERS, WHITEFLIES | 20. | 7596. | 22788. |

- Insecticide timing: F = foliar

Table 2. Insecticides: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Processing Tomatoes in California

| Insecticide | Treatment rate (lb ai/A) | Timing of treatment | Number Of Applications | Target pest | Acreage treated % of crop | Acreage treated acres | Pesticide Use (lb ai) |
|---|---|---|---|---|---|---|---|
| AZINPHOSMETHYL | 1.5 | F | 1. | FLEA BEETLES, FRUITWORMS | 2. | 5658. | 8487. |
| BT | 0.06 | F | 1.5 | BEET ARMYWORM, CABBAGE LOOPER, TOMATO FRUITWORM | 6. | 16974. | 1528. |
| CARBARYL | .091 | F | 1.3 | CUTWORMS, FLEA BEETLES | 17. | 48093. | 56894. |
| DIAZINON | .58 | F | 1.2 | APHIDS | 10. | 28290. | 19690. |
| DICOFOL | 1. | F | 1. | RUSSET MITE | 3. | 8487. | 8487. |
| DIMETHOATE | 0.4 | F | 1.2 | APHIDS, STINK BUGS | 8. | 22632. | 10863. |
| ENDOSULFAN | 0.95 | F | 1. | APHIDS, POTATO APHIDS, STINK BUGS | 4. | 11316. | 10750. |
| ESFENVALERATE | 0.04 | F | 1.2 | BEET ARMYWORM, TOMATO FRUITWORM, TOMATO PINWORM, WHITEFLIES | 36. | 101844. | 4889. |
| FONOFOS | 1. | F | 1. | APHIDS | 1.5 | 4243.5 | 4244. |
| MALATHION | 1. | F | 1. | APHIDS | 2. | 5658. | 5658. |
| METHAMIDOPHOS | 0.92 | F | 1.1 | POTATO APHIDS, STINK BUGS, LEAFMINERS | 30. | 84870. | 85888. |
| METHOMYL | 0.59 | F | 1.2 | TOMATO FRUITWORM, BEET ARMYWORM, WESTERN YELLOWSTRIPE ARMYWORM, TOMATO PINWORM | 23. | 65067. | 46067. |
| | | | | | | | |
| OXAMYL | 1. | F | 1. | APHIDS | 6. | 16974. | 16974. |
| SULFUR | 10. | F | 1. | RUSSET MITES | 40. | 113160. | 1131600. |

| Table 3. Herbicides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes | | | | | | | |
|---|---|---|---|---|---|---|---|
| Herbicide | Treatment rate (lb ai/A) | Timing Of Treatment | Number of applications | Target pest | Acreage treated | | Pesticide Use (lb ai) |
| | | | | | % of crop | acres | |
| DCPA | 5. | LB | 1. | ANNUAL WEEDS | 1. | 379.8 | 1899. |
| EPTC | 2. | LB | 1. | ANNUAL WEEDS, NIGHT SHADES | 5. | 1899. | 3798. |
| ETHEPHON | 0.87 | PH | 1. | RIPENING AGENT | 5. | 1899. | 1652. |
| GLYPHOSATE | 0.56 | PPF | 1`. | ALL WEEDS | 25. | 9495. | 5317. |
| METAM SODIUM | 19.1 | PP | 1. | ALL WEEDS | 10. | 3798. | 72542. |
| METRIBUZIN | 0.6 | PP, POE | 1. | ANNUAL WEEDS, NIGHT SHADES | 30. | 11394. | 6836. |
| NAPROPAMIDE | 1.06 | PPI | 2. | ANNUAL WEEDS | 6. | 2278.8 | 4831. |
| OXYFLUORFEN | 0.4 | PP | 1. | ANNUAL WEEDS | 5. | 1899. | 760. |
| PARAQUAT | 0.7 | PPF | 1. | ANNUAL WEEDS | 15. | 5697. | 3988. |
| PEBULATE | 4.81 | PPI, LB | 1.9 | ANNUAL WEEDS, NUTSEDGE | 10. | 3798. | 34710. |
| SETHOXYDIM | 0.28 | POE | 1. | ALL GRASSES | 5. | 1899. | 532. |
| TRIFLURALIN | 0.47 | PPI, LB | 1.4 | ALL WEEDS, SEEDLING FIELD BINDWEED | 31. | 11773.8 | 7747. |

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

| Table 4. Herbicides: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Processing Tomatoes in California | | | | | | | |
|---|---|---|---|---|---|---|---|
| Herbicide | Treatment rate (lb ai/A) | Timing of Treatment | Number of applications | Target pest | Acreage treated | | Pesticide Use (lb ai) |
| | | | | | % of crop | acres | |
| DCPA | 5. | LB | 1. | ANNUAL WEEDS | 1. | 2829. | 14145. |
| EPTC | 2.52 | LB | 1. | ANNUAL WEEDS, NIGHT SHADES | 5. | 14145 | 35645. |
| ETHEPHON | 0.87 | PH | 1. | RIPENING AGENT | 5. | 14145. | 12306. |
| GLYPHOSATE | .56 | PPF | 1.2 | ALL WEEDS | 54. | 152766. | 102659. |
| METAM SODIUM | 19.1 | PP | 1. | ALL WEEDS | 25. | 70725. | 1350848. |
| METRIBUZIN | 0.52 | PP, POE | 1.1 | ANNUAL WEEDS, NIGHT SHADES | 16. | 45264. | 25891. |
| NAPROPAMIDE | 0.86 | PPI | 1.1 | ANNUAL WEEDS | 60. | 169740. | 160574. |
| OXYFLUORFEN | 0.4 | PP | 1 | ANNUAL WEEDS | 8. | 22632. | 9053. |
| PARAQUAT | 0.61 | PPF | 1.5 | ANNUAL WEEDS | 5. | 14145. | 12943. |
| PEBULATE | 2.11 | PPI, LB | 1.2 | ANNUAL WEEDS, YELLOW NUTSEDGE | 25. | 70725. | 179076. |
| SETHOXYDIM | 0.14 | POE | 1. | ALL GRASSES | 2. | 5658. | 792. |
| TRIFLURALIN | 0.57 | PPI, LB | 1.1 | ALL WEEDS, SEEDLING FIELD BINDWEED | 95. | 268755. | 168509. |

| Table 5. Fungicides used in California: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Fresh Tomatoes | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Treatment rate (lb ai/A) | Timing Of Treatment | Number of applications | Target pest | Acreage treated % of crop | Acreage treated acres | Pesticide use (lb ai) |
| CHLOROTHALONIL | 1.52 | F | 1.9 | EARLY BLIGHT, LATE BLIGHT | 26. | 9874.8 | 28518. |
| COPPER | 0.79 | F | 1.8 | SPECK, SPOT | 18. | 6836.4 | 9721. |
| MANCOZEB | 1.34 | F | 1.8 | EARLYBLIGHT, LATE BLIGHT, GRAY MOLD | 5. | 1899. | 4580. |
| MANEB | 1.6 | F | 1.5 | EARLY BLIGHT | 2. | 759.6 | 1823. |
| METALAXYL | 0.18 | F, P | 1.6 | LATE BLIGHT, PHYTOPHTHORA ROOT ROT, BUCKEYE ROT | 15. | 5697. | 1641. |
| MYCLOBUTANIL | 0.1 | F | 1.8 | POWDERY MILDEW | 45. | 17091. | 3076. |
| SULFUR | 9.26 | F | 2. | POWDERY MILDEW | 5. | 1899. | 35169. |

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

| Table 6. Fungicides: Use patterns, Target Pests, Acreage Treated, and Pounds Pesticides Used on Processing Tomatoes in California | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Treatment rate (lb ai/A) | Timing of Treatment | Number of applications | Target pest | Acreage treated % of crop | Acreage treated acres | Pesticide use (lb ai) |
| CHLOROTHALONIL | 1.54 | F | 1.5 | EARLY BLIGHT, LATE BLIGHT, BLACK MOLD | 42. | 118818. | 274470. |
| COPPER | 1.27 | F | 1.3 | SPECK, SPOT | 22. | 62238. | 102755. |
| MANCOZEB | 1.6 | F | 1.5 | EARLYBLIGHT, LATE BLIGHT, BLACK MOLD | 10. | 28290. | 67896. |
| MANEB | 1.6 | F | 1.5 | EARLY BLIGHT | 2. | 5658. | 13579. |
| METALAXYL | 0.18 | F, P | 1.8 | LATE BLIGHT, PHYTOPHTHORA ROOT ROT | 20. | 56580. | 18332. |
| METAM SODIUM | 52.8 | PP | 1. | ROOT KNOT NEMATODE | 5. | 14145. | 746856. |
| MYCLOBUTANIL | 0.1 | F | 1.5 | POWDERY MILDEW | 15. | 42435. | 6365. |
| SULFUR | 21.04 | F | 1.6 | POWDERY MILDEW | 5. | 14145. | 476177. |

| Table 7. 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 8. Insects: Nonchemical Control Practices for Processing Tomatoes Pests in California | | | |
|---|---|---|---|
| | | Acreage where practiced | |
| Control practice | Target pests (efficacy) | % of crop | acres |
| FALLOW | TOMATO PINWORM (1) | 5. | 14145. |
| PARASITE RELEASES | ARMYWORM (5), TOMATO FRUITWORM (4), HORNWORM (4) | 6. | 16974. |

**Table 9. Ranking of Economically Important Tomato Weeds in California by Impact on Yield**

| | |
|---|---|
| *Solanum spp.* (Nightshades/Groundcherry) | 1 |
| *Cyperus* spp. (Nutsedge) | 1 |
| *Echinochloa crus-galli* (Barnyardgrass) | 1 |
| *Convolvulus spp.* (Bindweed) Estab. | 1 |
| *Amaranthus spp.* (Pigweeds) | 2 |
| *Sorghum halepense* (Johnsongrass) Estab. | 3 |
| *Cynodon dactylon* (Bermudagrass) Estab. | 3 |
| Volunteer cereals | 3 |
| *Chenopodium album* (Lambsquarters) | 4 |
| *Digitaria spp.* (Crabgrass) | 4 |
| *Abutilon theophrasti* (Velvetleaf) | 4 |
| *Portulaca oleracea* (Purslane) | 4 |
| *Datura stramonium* (Jimsonweed) | 5 |
| *Convolvulvus spp.* (Bindweed) Sdlg. | 5 |
| *Sorghum halepense* (Johnsongrass) Sdlg. | 5 |
| *Cuscuta spp.* (Dodder) | 5 |
| *Ipomoea spp.* (Morningglory) | 5 |
| *Cynodon dactylon* (Bermudagrass) Sdlg. | 5 |
| *Malvaceae* (Mallow/Cheeseweed/Sida) | 6 |
| *Xanthium spp.* (Cocklebur) | 6 |
| *Brassica spp.* (Mustards) | 6 |
| *Erigeron spp.* (Fleabane) | 7 |
| *Conyza spp.* (Fleabane/Horseweed) | 7 |
| *Urtica spp.* (Nettle) | 7 |
| *Lactuca serriola* (Prickly Lettuce) | 7 |
| *Senecio spp.* (Groundsel) | 7 |
| *Sonchus spp.* (Sowthistle) | 7 |
| *Eleusine indica* (Goosegrass) | 7 |
| *Orobanche ssp.*(Broomrape) | 8 |
| *Salsola tragus* (Russian Thistle) | 8 |
| *Sisymbrium irio* (London Rocket) | 8 |
| *Setaria spp.* (Foxtails) | 8 |
| *Eragrostis spp.* (Lovegrass/Stinkgrass) | 9 |
| *Capsella bursa-pastoris* (Shepherdspurse) | 9 |
| *Stellaria spp.* (Chickweed) | 9 |
| *Phalaris spp.* (Canarygrass) | 9 |
| *Avena fatua* (Wild oats) | 9 |
| *Helianthus annuus* (Sunflower) | 9 |
| *Leptochloa spp.* (Spangletop) | 9 |
| *Trifolium spp.* (Clover) | 9 |
| *Proboscidea spp.* (UnicornPlant/Devilsclaw) | 10 |

| Table 10. 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. |

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

| Table 11. Weeds: Nonchemical Control Practices for Processing Tomatoes Pests in California | | | |
|---|---|---|---|
| | | Acreage where practiced | |
| Control practice | Target pests (efficacy) | % of crop | acres |
| CROP ROTATION | ALL WEEDS, PARTICULARLY FIELD BINDWEED (2), NIGHTSHADE (2) | 98. | 277242. |
| CULTIVATION | ALL WEEDS EXCEPT DODDER (3) | 100. | 282900. |
| DRIP IRRIGATION | ANNUAL WEEDS (2) | 5. | 14145. |
| HAND WEEDING | ALL WEEDS (2) | 100. | 282900. |
| PROPANE FLAMING | ALL WEEDS (2) | 1. | 2829. |
| SOIL CAP AT PLANTING | ALL ANNUAL WEEDS (3) | 2. | 5658. |
| TRANSPLANTNG | EARLY SEASON WEEDS (3) | 2. | 5658. |

| Table 12. 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.

| Table 13. Plant Diseases: Nonchemical Control Practices for Processing Tomato Pests in California | | | |
|---|---|---|---|
| | | Acreage where practiced | |
| Control practice | Target pest | % of crop | acres |
| CROP ROTATION | ROOT KNOT NEMATODE (4), SPECK (2), SPOT (2), PHYT.ROOT ROT (2), BUCKEYE ROT (2) | 90. | 254610. |
| DELAY PLANTING | SPECK(1), SPOT(1) | 25. | 70725 |
| DISEASE FORECASTING | BLACKMOLD (3) | 3. | 8487. |
| EARLY HARVEST | BLACKMOLD (3) | 25. | 70725. |
| FALLOW | ROOT KNOT NEMATODE (3) | 0.01 | 28. |
| IRRIGATION MANAGEMENT | SPECK (2), SPOT (2), PHYT.ROOT ROT (2), BUCKEYE ROT (2), BLACKMOLD (2), LATEBLIGHT (2) | 50. | 141450. |
| RESISTANT VARIETIES | VERTICILLIUM WILT (2), SPECK (1), ROOT KNOT NEMATODE (1), FUSARIUM WILT (1) | 95. | 268755. |