Pest Management Strategic Plan

California Fresh Market Tomato Production

Prepared for the
United States Department of Agriculture and the
Environmental Protection Agency

By the

California Tomato Commission

and the

California Minor Crops Council

June, 2003

Table of Contents

Executive Summary …………………………………………………………………………………………3
California Fresh Market Tomato Production Overview ………………………………………………………6
Fresh Market Tomato Production Regions with Califomia Map ……………………………………………7
Tomato Crop Phenology ……………………………………………………………………………………8
Foundation for a Pest Management Strategic Plan ………………………………………………………8
  Land Preparation to Transplanting Period ………………………………………………………………9
  Early Season Pests – Direct Seeding to Emergence/Transplanting ……………………………………10
  Pests During Flowering and Fruit Development …………………………………………………………17
  Plant Growth Regulators ……………………………………………………………………………26
  Fruit Maturity, Harvest and Post-Harvest…………………………………………………………………27
Food Safety ……………………………………………………………………………………………28
International Trade and Export …………………………………………………………………………29
Critical Pest Management Needs for the California Fresh Tomato Industry ………………………………30
IR-4 Project Information Relative to California Fresh Market Tomatoes ……………………………………31
References ……………………………………………………………………………………………33
Appendices
  California Fresh Tomato Production Statistics – Year 2000 ………………………………………………36
  Cultural and IPM Activities Time Lines for California Fresh Tomatoes
    Northern San Joaquin Valley …………………………………………………………………………37
    Southern San Joaquin Valley …………………………………………………………………………37
    Central Coast ……………………………………………………………………………………38
    Southern Coast …………………………………………………………………………………38
    Imperial Valley …………………………………………………………………………………39
  Seasonal Pest Occurrence Time Lines
    Northern San Joaquin Valley …………………………………………………………………………40
    Southern San Joaquin Valley …………………………………………………………………………41
    Central Coast ……………………………………………………………………………………42
    Southern Coast …………………………………………………………………………………43
    Imperial Valley …………………………………………………………………………………44
  Efficacy Tables
    Insecticide Efficacy: Insect Management Tools in California Tomatoes ……………………………45
    Efficacy of Non-Chemical Insect Management Tools ……………………………………………46
    Relative Toxicity of Insecticides to Beneficial Organisms …………………………………………47
    Fungicide Efficacy: Disease Management Tools in California Tomatoes ……………………………48
    Nematicide Efficacy: Nematode Management Tools in California Tomatoes …………………………49
    Herbicide Efficacy: Weed Management Tools in California Tomatoes ……………………………50
    Efficacy of Vertebrate Control in California Tomatoes ……………………………………………51
  Chemical Use – (1998 – 2002)
    Insecticide Use in Total Pounds Active Ingredient & % Acres Treated………………………52/53
    Herbicide Use in Total Pounds Active Ingredient & % Acres Treated…………………………54
    Fungicide Use in Total Pounds Active Ingredient & % Acres Treated…………………………55
    Nematicide Use in Total Pounds Active Ingredient & % Acres Treated………………………56
    Plant Growth Regulator Use in Total Pounds A.I. & % Acres Treated …………………………56
  Members of the Fresh Market Tomato Work Group ……………………………………………………57
  California Tomato Commission Review Team ……………………………………………………………57
  California Fresh Tomato Industry – Work Group Contact Information ………………………………58

Executive Summary

The new safety standards set forth by the Food Quality Protection Act (FQPA), under review by the Environmental Protection Agency (EPA), will impact the use of certain crop protection tools used by the agricultural community. In order to facilitate this transition to "Reduced Risk" pest management, the United States Department of Agriculture (USDA) has requested that all commodity groups develop a "Pest Management Strategic Plan" (PMSP) to identify the critical research, registration, and educational needs for their specific commodity. "Reduced Risk" is a very broad term used to describe pest management techniques and tools that have low inherent toxicities and those that have a minimal impact on the environment.

For California tomato growers in particular, the label registrations of azinphos methyl (Guthion) and methamidophos (Monitor) are examples of products which are being modified, cancelled, or restricted due to FQPA. Due to the possible loss of these or other valuable crop protection tools, coupled with widespread reductions in funding and Land Grant University personnel to conduct field research and extension programs, it is imperative that all resources be used in the most efficient manner possible. The objective of this strategic plan is to develop a comprehensive list of critical concerns of the fresh tomato industry in California and to recommend means to address these priorities with the most appropriate resources in the areas of research, registration, and education.

This strategic plan includes an overview of fresh market tomato production, cultural practices, seasonal pest occurrences, and management techniques throughout the state. Both current and emerging pest management needs are addressed in this plan. Efficacy ratings of various pest control techniques (chemical and non-chemical) used in tomato production have been summarized from input made by growers, Pest Control Advisers (PCAs), researchers, and other experts involved in field activities. As a result of the PMSP meeting held on January 29, 2002, several critical areas have been identified by the fresh tomato industry. In addition, the pest management sub committee of the California Tomato Commission (CTC) provided valuable input at their meeting on September 10, 2002. The following priority areas, listed in order of importance, must be addressed in order to maintain the long-term viability of this industry.

<u>Research Priorities</u>*:* Finding practical solutions to insect control are of immediate and serious concern to producers of fresh market tomatoes in California.

1) Of paramount importance is the need to find effective alternatives to rotate with methamidophos (Monitor), a highly efficacious organophosphate insecticide used for stink bug control. This material, along with other chemicals in this class of chemistry, has received intense scrutiny and is under threat to be removed or have the label modified as a crop protection tool.
2) Research is needed on vector biology. Disease management strategies for control of whiteflies/infectious viruses, thrips/tomato spotted wilt virus, leafhoppers/curly top virus, aphids/Poly viruses, and tomato psyllid/yellows virus also need to be developed. The understanding of the basic biology of disease/vector relationships is critical to the industry, especially for learning how to avoid and reduce losses from viruses.
3) Tomato growers are concerned about effective control of soil pests and safer alternatives need to be developed to rotate with organophosphates and carbamates.
4) Development of pest resistant tomato varieties needs to be encouraged, advanced, and incorporated into existing seed development research. Plant breeding research should find

and develop new tomato varieties that are resistant to the many plant diseases and insect pests that are problems for the grower.

5) Weed control is also a key area to address. Development of new technologies and techniques to manage field bindweed, nutsedge, and nightshade is needed.
6) The work group agreed that a "low input systems approach" to managing all pests of tomatoes should be a focus in future research programs.
7) Development of safe and cost-effective control of post harvest pathogens needs to be researched and evaluated.
8) Crop management alternatives such as the use of cover crops and reduced tillage need to be studied to identify impacts on insect pest management, with emphasis on both field and regional management.

Regulatory Priorities: The most important regulatory action that needs to be done involves an enhanced interaction between Cal-EPA and US-EPA.

1) Harmonization between Cal-EPA and US-EPA should be encouraged to facilitate and hasten the registration of reduced risk products. It now appears that concurrent registrations of pesticide labels on a federal and state level have been lost. Budget cuts at the state level at the California Department of Pesticide Regulation (CDPR) would force a longer waiting period for state reviews. Any delay in getting the federal pesticide label approved for use in California puts our growers at a disadvantage when materials get approved first in other states.

In terms of specific registrations, the tomato industry also needs:

2) New products registered to rotate in an insect pest resistance program with methamidophos (Monitor) for stink bug control.
3) New chemistries for late blight and powdery mildew control and overall disease resistance management.
4) Clarification of the label of imidacloprid (Admire) for use with greenhouse transplants.

Educational Priorities: The fresh market tomato industry has been very proactive in providing educational opportunities for growers and PCAs with considerable cooperation from personnel with the University of California (UC) and also USDA researchers. In addition, the CTC has been involved with the Pesticide Environmental Stewardship Program (PESP) at the federal level to identify strategies for reduced risk. Specific targets for new educational opportunities are:

1) Educate government agencies on unfair trade/cultural practices, which result from regulatory burdens.
2) Regulators and consumer groups must be educated as to how Integrated Pest Management (IPM) practices are used in fresh tomatoes and how this system optimizes food production while it minimizes risks to workers and the environment. This is especially important as it relates to risk assessments for crop production.
3) The general public needs to understand how IPM is used in agriculture and how changes brought about by the FQPA review impacts on the cost of food. The economic side of replacing low-cost pesticides with newer, but much more expensive, materials needs to be considered in the review process.
4) With a very diversified crop production system in the state, all growers need to be educated on the value of a crop free period in terms of reducing future pest infestation levels and related pesticide applications when overlapping cropping patterns are employed around their fields. This would focus on area-wide pest management.

5) Finally, the public should be reminded through effective media (e.g., “Buy California”, “Five a Day” programs) that the consumption of fresh fruits and vegetables, particularly fresh tomatoes, contributes to a nutritious diet and healthy lifestyle.

The industry has also appreciated efforts made by numerous individuals on field days with EPA, CDPR, and USDA representatives to discuss and highlight areas of concern and identify educational opportunities at both federal and state levels.

It is hoped that this strategic plan will serve as a resource for those wanting to learn more about the production of fresh market tomatoes in California and especially those issues associated with pest management. A comprehensive list of growers, PCAs, industry representatives, and UC research and extension personnel is provided to identify individuals with expertise in particular areas.

This PMSP has been prepared with an immediate time frame of three to five years. The tomato industry will periodically review, adjust, and update priorities to remain current with industry developments and issues. The California fresh market tomato industry appreciates the support and assistance of EPA, USDA, CPDR, and the UC Land Grant system as we seek to find solutions for the many issues facing this important industry.

For the sake of all readers, the pesticide names identified in the body of this report will be shown in both the approved common name and the registered trade name as growers and PCAs are more familiar with the registered trade name. The American National Standards Institute and the International Standards Organization have approved of common names of pesticides. Please see the Glossary of Pesticide Chemicals listed in the reference section of this report for the latest glossary version. In addition, the scientific name will be identified along with the common pest name.

Major funding for this project was accomplished through grants to the California Minor Crops Council from the EPA Region 9 Agricultural Initiative and the USDA Cooperative States Research, Education, and Extension Service (CSREES) “Pest Management Alternatives Program (PMAP)” programs. Additional support was provided through the California Tomato Commission and the California Pest Management Center at UC Davis. We are extremely grateful for the contributions of all of these organizations and their active participation in this process.

The mention of any specific product in this document does not represent endorsement by any member or organization within the California Fresh Market Tomato Work Group.

California Tomato Commission California Minor Crops Council

California Fresh Market Tomato Production Overview

- In year 2000, California was the number two state in US fresh market tomato production with 35.5% of the total. Fresh tomatoes ranked 22nd in value among all commodities grown in the state. The year 2000 was considered by some to be a banner year with above average yield and price.
- A total of 584,707 tons of fresh tomatoes were produced on approximately 39,000 acres in 2000. The average yield was 15.2 tons/Acre (range of 10.5 – 20.9 tons/A).
- The average price paid for packed and loaded fresh tomatoes was $460 per ton with a total cash value of $270 M (gross = $6980/A).
- Approximately 15% of the total tomato acreage in the state is for the fresh market.
- Most consumption of California tomatoes is through domestic markets. Approximately 20% are exported, mainly to Canada, Mexico, and Japan.
- The tomato plant, *Lycopersicon esculentum*, is a warm season annual plant that has been cultivated with hybrid varieties dominating the market. Tomatoes belong to the botanical family Solanaceae and thus, some newer technical references will show *Solanum lycopersicum* as the genus species name.

Production Regions

There are five commonly recognized areas of fresh market tomato production. These areas can be seen on the state map shown in Figure 1 on page 7.

Area I, the northern San Joaquin Valley, grows about 60% of the state's fresh market tomatoes (mostly bush type) with production in Merced, San Joaquin, and Stanislaus counties and minor plantings in Sacramento, Santa Clara, and Contra Costa counties. Production in this area has increased as 45% of the state’s acreage was produced in this region in 1998. Planting of fresh market tomatoes is from February to June with harvest from mid-July to late October. Rainfall varies from about 26 inches per year in the Sacramento Valley to about 16 inches per year in Modesto and 12 inches in Merced in the northern San Joaquin Valley.

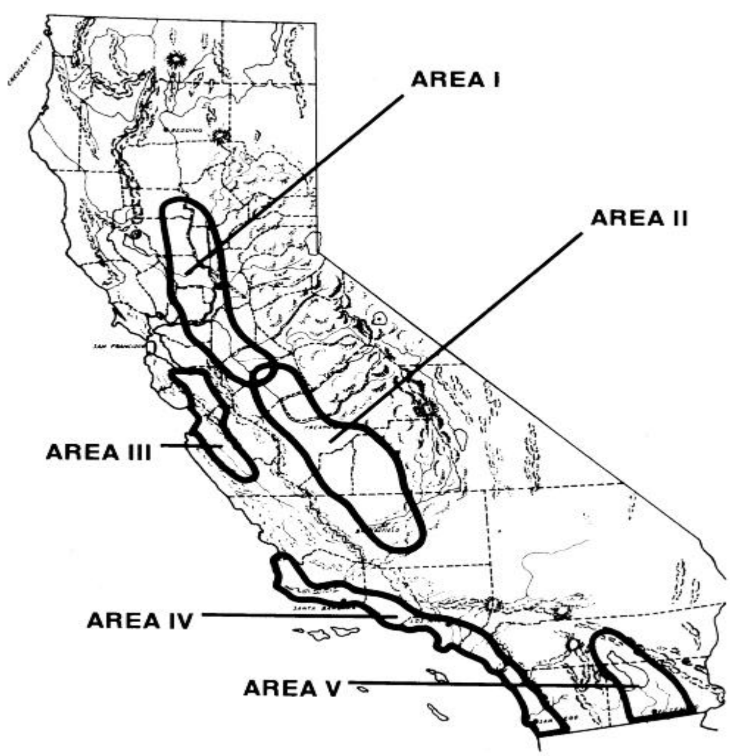
Area II, the southern San Joaquin Valley (south of Merced County) produces about 27% of the fresh market tomatoes. Production of bush type tomatoes occurs in Fresno, Kern, Kings, and Tulare counties. Production in this area has slightly decreased as 30% of the state’s acreage was produced in this region in 1998. Fresh market tomatoes are planted from February to March with a harvest period from mid-June into September. Fresno receives about 10 inches of rainfall per year while Kern County can receive about three inches per year.

Area III, the Central Coast, produces about 3% of the state's fresh market tomatoes (bush type) in Monterey and San Benito counties. Production in this area has decreased due to late blight pressure as 10% of the state’s acreage was produced in this region in 1998. The planting period is from March to May and harvest is from August to October. Average rainfall is 20 inches per year.

Area IV, the South Coastal area, grows about 9% of the state's fresh market tomatoes with production occurring in San Diego and Orange counties. This area produced approximately 10% of the state's 1998 fresh crop, so acreage has remained stable despite significant greenhouse whitefly pressure in recent years. Spring pole tomatoes are planted from January through March and are picked from May through July. Summer crops are planted from March through May and are harvested from July to October. The fall crop of fresh market tomatoes is planted in June and July and is harvested from September to December. Typical rainfall amounts are 11-12 inches per year.

Area V, the Imperial Valley, grows about 1% of the state's fresh market tomatoes with production in Imperial County. Production in this area has decreased as about 5% of the state's acreage were produced in this region in 1998. Planting starts in January and goes to March, with harvests from May into June. This area produces bush type tomatoes with typical rainfall amounts of less than four inches per year.

Figure 1. Fresh Market Tomato Production Regions in California



This strategic plan reports on production of mature green bush type and also pole type tomatoes grown in California. Greenhouse grown and cherry tomatoes are two other types produced in a minor market and specific pesticide use and cultural information are not being provided. Production statistics for the main tomato types can be found in the appendix.

Bush type tomatoes, the predominate variety type, are free standing plants with a typical once over harvest that may be picked a second time if market conditions are favorable. Pole type tomatoes are tied to trellises and are harvested in numerous picks throughout the season with a common harvest pattern of two to three times per week.

Tomato Crop Phenology

The following table shows the typical fresh tomato crop phenology events, shown in days, involved from transplanting to fruit set to harvest for the main production regions.

Table 1 Fresh Tomato Crop Phenology in Days

Location	Transplanting Date	Days from Transplanting to Fruit Set	Days from Fruit Set to First Harvest	Harvest Period in Days
Oceanside Area IV	Jan. 15 July 1	50 40	55 45	Up to 70 Up to 100
Imperial Valley Area V	Feb. 1	55	55	Once over Harvest
Salinas Valley Area III	May 1 July 1	60 45	65 55	Once over Harvest
Merced Areas I, II	Apr. 1 June 1 Aug. 1	50 40 40	50 45 50	Once over Harvest

Foundation for a Pest Management Strategic Plan

Members of the California fresh market tomato industry representing researchers, growers, packers, shippers, commodity groups, and PCAs, were asked to join a work group with invited representatives from the USDA, EPA, and the California Pest Management Center. The goal was to lay a foundation for the development of a strategic plan for pest control problems of significant concern to California fresh tomato growers and handlers. Their input provided an important viewpoint to the pesticides and alternatives used and to the diversity of IPM practices for the major growing regions of the state. All members of the California Fresh Tomato Work Group and their affiliations are identified with contact information provided at the end of this report.

The remainder of this document is an analysis of agronomic practices, pests, and pest management tools used during the major stages of the tomato production season. In some cases, certain sections will be divided by area, or season, to describe regional differences. Time lines of seasonal pest occurrence, pest management field activities, and cultural practices for each production area are provided in the Appendix. A comprehensive overview of tomato production practices, pests, and control techniques, have been previously identified in the Crop Profile for Fresh Market Tomatoes in California (1999).

The critical issues of the fresh market tomato industry in California have been presented in this strategic plan according to the time during the production season in which they occur, e.g., early season, fruiting, etc. A "To Do" list has been developed for each issue raised by the working group. In order for the industry to address these topics in the most systematic manner possible, the issues have been listed according to whether they fall into the categories of research, regulatory, or educational needs.

Land Preparation to Transplanting Period

Land preparation is the first step before planting tomatoes. Almost all tomatoes are transplanted on raised beds in California to facilitate subsequent cultivation and irrigation of the tomato crop, as well as to improve drainage, which minimizes root diseases. Fallow bed herbicide treatments are sometimes used to prevent winter weed growth and to allow for tomato planting in early spring.

Most tomatoes are transplanted (>95%) in order to provide a head start on weeds and to reduce stand establishment problems. Transplants, however, have a weaker taproot and more secondary roots than do direct seeded tomatoes and are more subject to virus problems. A small amount of fields are direct seeded at high seeding rates to insure a good stand, and these fields will be subsequently thinned by hand crews several weeks after tomato emergence.

Irrigation is used for all California tomatoes and may be through furrow, sprinkler, or drip systems. Furrow irrigation is commonly used in tomatoes and proper grading is critical for good drainage and for reducing disease levels. Sprinkler irrigation can be used to germinate a direct seeded crop, but this type of system is rarely used after fruit set, as the use of sprinklers increase fruit diseases. Drip irrigation is used on over half the fresh market tomatoes grown in California as it provides for good water management and allows hand harvesting at regular intervals. Drip irrigation systems are also used extensively in tomato plantings in areas with rolling terrain (Area IV). Subsurface drip irrigation is used in some areas; especially where salt buildup in the soil is a problem.

Weed management is a key component of fresh market tomato production in California. Practices may be done "in season" and/or "out of season" and the techniques used vary according to predominant weed species, location, irrigation systems, and cost. Weed control may be done with herbicides, cultivation, hoeing, or flaming. The various timings are classified as follows:

- Fall bed treatments – done before weeds emerge and crop is planted
- Fall bed treatments – done after weeds emerge but prior to planting
- Preplant – done before weeds emerge, but shortly before crop is planted/transplanted
- Layby – after crop is planted but before weeds emerge (Usually done with direct seeded tomatoes only)
- Postplant – after crop is planted and after weeds have emerged

Early Season Pests – Direct Seeding to Emergence/Transplanting

Insects

Pest Control Advisers monitor early season insect pests by examining plants, nearby soil, and associated soil clods shortly after fields are planted or transplanted. Adjacent fields and vegetation are usually also checked to see if there are pest species migrating into tomato fields. Chemical controls for these insects include organophosphate and carbamate baits and pyrethroids.

Variegated Cutworms (*Peridroma saucia*) and Black Cutworms (*Agrotis apsilon*) are the most common cutworm species found in California tomato fields. Cutworms are serious insect pests of emerging and young tomato plants. They are generally night feeders and chew through stems at or near the soil line, reducing the stand. Cutworms are effectively controlled using carbaryl (Sevin) bait. Permethrin (Pounce) is also a very good product, however, this pyrethroid is used judiciously as overuse may cause leafminers or thrips populations to flare up later in the season. Sanitation is a key cultural control practice used to reduce these pests as cutworms are harbored in vegetative trash and weeds. Natural biological control occurs after cultivation as birds eat the exposed larvae in the soil.

Darkling Ground Beetles (*Blapstinus spp*. and others) also feed on young plants near the soil line and usually are most prevalent at the edges of weedy or fallow fields. Darkling ground beetles can be effectively controlled with carbaryl (Sevin) or Diazinon applications.

Flea beetles (*Epitrix hirtipennis*) chew holes in leaves and stems, weakening the tender plants. Flea beetles are also effectively controlled with carbaryl (Sevin) applications. Esfenvalerate (Asana XL) is effective when run through a solid-set sprinkler system, although this is not a common practice as much as ground rig applications of esfenvalerate are. Ground rig applications of Provado (imidacloprid) in bands have been effective as well as that of permethrin (Pounce). Foliar applications of methomyl (Lannate) or oxamyl (Vydate) provide good control of flea beetles, which typically have a very short window of being a pest in tomatoes.

Wireworms (*Limonius* spp. and others) are click beetle larvae that dwell in the soil. The pest has been found in all soil types in the tomato production regions. Damage consists of feeding on roots and boring into plant stems. Wireworms are controlled fairly well with Diazinon granules incorporated into the soil. There are, however, problems with this product in that phytotoxicity can occur if the tomatoes are direct seeded. Crop rotation can be effective in reducing wireworm infestations in soil and common crops for this rotation include safflower, beans, cotton, melons, and corn.

Garden symphylans (*Scutigerella immaculata*), commonly referred to as garden centipedes, are an occasional pest that may damage young plants. The pest can be found in the same part of a field each year as the insect infestation slowly spreads to other parts. The pest can be a bigger problem in fields with high amounts of organic matter. Diazinon granules incorporated into the soil provides fair to good control.

Whiteflies can be a problem throughout the season. Species compositions vary by geography. The silverleaf whitefly (*Bemisia argentifolii*) is the primary whitefly species in the desert production area while the greenhouse whitefly (*Trialeurodes vaporariorum*) is the species of concern in the south coastal area. Imidacloprid (Admire) provides excellent early-season control of these pests, although pest populations can build up later in the season and create problems. Insect pest resistance is a big concern for growers in Area IV. Whiteflies can transmit viruses that can do more damage than the actual insect feeding. Silverleaf whitefly is the primary vector for Tomato Yellow Leaf Curl Virus and it also can carry Tomato Chlorosis Virus (ToCV). Greenhouse whitefly is the only known vector for Tomato Infectious Chlorosis Virus (TICV) but it also can vector ToCV.

Western Flower Thrips (*Frankliniella occidentalis*) can damage tomatoes with their rasping-chewing mouthparts during any stage of plant growth. Thrips transmit tomato spotted wilt virus in the desert and in southern California regions. Thrips have also been suspected to inflict fruit blemishes in Area II. Spinosad (Success) provides good initial control but doesn't have any residual activity, which is of concern when the flying insects quickly fly in from surrounding fields.

Tomato psyllids (*Paratrioza cockerelli*) have become a problem in recent years in the south coastal area. Psyllids can transmit yellows virus. Research is needed to identify proper control strategies. The use of imidacloprid (Admire) at planting in the desert region, Area V, offers some control of tomato psyllids.

Beet leafhopper (*Circulifer tenellus*) can be a pest throughout the growing season so this species should be monitored the entire season, especially in Area II. There can be some feeding damage done to tomato plants but the biggest problem is that beet leafhoppers are the vector for curly top virus. Tomatoes are not considered to be a suitable host for beet leafhoppers as the feeding is usually minimal but long enough to transfer the virus. Fallow field management is an effective means to manage infestation levels in tomato fields close by to foothills of the coastal range, however there are economic concerns with leaving a field out of production. Lannate (methomyl) provides good control of leafhoppers, but it has very short residual activity and its use for this pest is minimal. Imidacloprid (Admire) controls leafhoppers. Malathion is the product effectively used in the state regulatory program for curly top virus control.

Potential problems

Spotted cucumber beetles (*Diabrotica undecimpunctata*), particularly the larval stage, have started to become a problem throughout the coastal production regions and especially for organic growers in the San Joaquin Valley. Spotted cucumber beetles have historically been controlled by organophosphate or carbamate spray applications or with Sevin bait. As overall pesticide use has been reduced through IPM, or changes in use patterns of specific materials have been implemented, the importance of various pest species has shifted. This may be the case with an increase of cucumber beetles as more vegetable crop production has replaced some small grain and cotton acreage. Chewing damage can occur on tomato stems, flowers, and fruit.

Aphids can cause feeding damage to tomatoes and can vector viral diseases. Potato aphids (*Macrosiphum euphorbiae*) are usually a minor pest but they can show up each year and establish colonies as the pest is heat tolerant. Green peach aphid (*Myzus persicae*) can be a problem in early spring. There has been some additional concern that the cotton/melon aphid (*Aphis gossypii*) could move into tomatoes in late plantings. Aphids are controlled very well by imidacloprid (Admire), but good coverage is critical. Pymetrozine (Fulfill) is a rather new compound so no usage patterns have been established in the pesticide tables in this report. Pymetrozine (Fulfill) has been reported by PCAs to be very effective and soft on beneficial organisms, but it is only registered for ground applications. A new compound for aphid control is acetamiprid (Assail) which is reported by PCAs to work well if used on the front end of production where one week of control could be expected under moderate pest pressure.

Additional Information on Controls

Cultural Control: No new techniques reported.
Biological Control: No commercially acceptable techniques available.

New Chemistry: Actara (a neonicotinoid) could be promising as this is not supposed to have cross-resistance with imidacloprid (Admire).

A "TO DO" List for Management of Early Season Insects in Tomatoes (listed in order of importance):

Research:

1) Evaluate materials for control of whiteflies and other insects with sucking mouthparts (such as Actara for aphids).
2) Evaluate carbamate alternatives for use in baits (e.g., neonicotinoids).
3) Study psyllid biology and control.
4) Continue Genomics work on novel peptides for control of phloem feeding insects with Dr. Brian Federici (UC BioSTAR).
5) Develop whitefly resistance management program for tomatoes.
6) Develop insect and virus resistant plant varieties.

Regulatory:

Register plant drenches for use in greenhouse production.

Education:

1) Provide training on application technology effective on specific pests.
2) Continue to train growers on pest identification and damage.

Weeds

Herbicides were used for weed control on 56% of the fresh tomatoes grown in California in 2000 while herbicides were used on 63% of the US fresh tomato crop. Integrated weed control practices (cultural, hand weeding, chemical, etc.) are used in almost all tomato fields. This process begins with field surveys to identify weed species and then appropriate practices and herbicides are selected.

Weed control alternatives range from cultural to chemical. Cultural practices include crop rotation, cultivation, and hand weeding (hoeing). Water management, can be effective in reducing weed germination and this is one reason why drip irrigation is used extensively in some fresh market tomato regions in the state. Adjusted planting dates help to avoid competition from certain weeds (e.g., barnyard grass and dodder). Some research has focused on the identification of tomato varieties that are highly competitive or resistant to certain weeds (e.g., dodder), however, no new varieties with these characteristics have been developed thus far.

A variety of weed control practices may be used at different times of the year. There are four main timings for weed control activities: fall bed treatments, preplant, postplant, and layby treatments. The UC has published an excellent herbicide efficacy chart describing the use of these materials in the UC IPM Pest Management Guidelines: Tomato (Updated 2001).

Fall bed treatments are often applied to fields 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 dry periods in early spring. In later plantings (March to June), non-selective herbicides, cultivation and preplant incorporated herbicides can all be used. More costly herbicides are applied as band treatments.

Fall Bed Treatments - Before Weeds Emerge

Cultivation, cover crops, and mulching with plastic are effective ways to manage fall weeds. Chemicals used during this time include metribuzin (Sencor) and napropamide (Devrinol) which are both broadleaf herbicides with little activity on grasses. Metribuzin (Sencor) is considered to be a slightly broader spectrum material as compared to napropamide (Devrinol). Oxyfluorfen (Goal) can also be used before weeds emerge.

Fall Bed Treatments – After Weeds Emerge

Cultivation and hoeing are effectively used as management tactics in the fall after weeds have emerged. Some conventional and organic growers use flaming as a weed control technique but it can be both labor intensive and costly due to the high cost of propane. Flaming can be used on small weeds but is somewhat ineffective for control of tall grass species.

Chemicals effectively used at this time include paraquat (Gramoxone Extra), glyphosate (Roundup), and a Roundup/Oxyfluorfen (Goal) combination. If oxyfluorfen (Goal) herbicide is used, the beds will have to be worked prior to planting because of potential carryover problems in the root zone.

Glyphosate (Roundup) and oxyfluorfen (Goal) are broad-spectrum contact herbicides with activity on several weed species. Glyphosate (Roundup) is broader spectrum and picks up more of the grass species as compared to oxyfluorfen (Goal), which is a very costly herbicide. Another good broadleaf herbicide is 2-4,D; however, its use is highly restricted due to drift concerns into nearby crops.

Preplant – Before weeds emerge

Cultivation is done as management tactics prior to planting. Several herbicides are used at this time for weed control: pebulate (Tillam), trifluralin (Treflan), napropamide (Devrinol), rimsulfuron (Matrix), metam-sodium (Vapam) and methyl bromide. Metolachlor (Dual MAGNUM) has recently received a Section 24(c) Special Local Need (SLN) label for use in controlling yellow nutgrass (nutsedge) in transplanted and seeded tomatoes.

Postplant – After weeds emerge

Cultivation/soil covering and hoeing are options, as well as flaming. Metribuzin (Sencor), sethoxydim (Poast), rimsulfuron (Matrix) and clethodim (Prism) are used primarily for grass control. Rimsulfuron (Matrix) is a relatively new material that provides fair to good dodder control.

Layby – After crop established and before weeds emerge

Layby treatments are done primarily in direct seeded fields and chemical treatments include EPTC (Eptam), Acetamide (Dual MAGNUM), trifluralin (Treflan), pebulate (Tillam), mainly for nutgrass (nutsedge) and annual grass control.

Annual grasses

Trifluralin (Treflan) is commonly used as a preplant or layby treatment and generally provides good control of grasses. Erratic results may be due to improper soil incorporation and activation with water. Napropamide (Devrinol) may also be used preplant, and control ranges from fair to good for broadleaves. Pebulate (Tillam) also provides fair to good control of broadleaf weeds.

Additional Information on Controls

Cultural Control: No new techniques reported.
Biological Control: None indicated.

New Technology: Conservation tillage and precision cultivation.
New Chemistry: Halosulfuron (Sandea) – for postemergence control of nutsedge.

A "TO DO" List for Early Season Weed Management in Tomatoes:

Research:
1) Evaluate materials and techniques for bindweed control.
2) Develop resistant/tolerant varieties to dodder.
3) Develop precision cultivation techniques.

Regulatory:
Register pendimethalin (Prowl).

Education:
Educate growers on conservation tillage and precision cultivation.

Diseases

A complex of organisms contributes to "damping off" or loss of emerging and very young plants. Organisms responsible for this syndrome include: *Rhizoctonia*, *Phytophthora*, and *Pythium*. In general, cool, damp conditions in combination with poor drainage and compacted soils will predispose a field to infection by these pathogens. *Verticillium* wilt is also a widespread disease that can develop in the early part of the season. Using resistant varieties, clean seed and seed treatments are very effective ways to avoid disease problems in young stands. Field sanitation and reducing soil movement from adjacent fields into tomato fields also reduces the potential for disease development.

Rhizoctonia, *Phytophthora*, *Pythium*, and *Verticillium* are all soil borne diseases in which the controls are basically the same for all. Most greenhouse transplants are grown in sterilized soils and therefore these diseases are not commonly a problem. Good field and water management can significantly reduce problems caused by these pathogens. Promote is a new beneficial fungus that has been suggested as a biological control for these soil borne fungi, although UC personnel have developed no data. Effective chemical controls include metalaxyl (Ridomil) used through the drip system and metam-sodium (Vapam), which varies in efficacy according to proper application technique and soil moisture. Methyl bromide is used as a preplant fumigant in the south coast and desert production areas, however, this material is being phased out and alternatives definitely need to be evaluated.

<u>Late blight</u> (*Phytophthora infestans*) is the most serious plant disease that threatens tomatoes grown in California. Like other diseases, greenhouse management is key to limiting problems with this pathogen on transplants. Sanitation also helps to reduce the incidence of this disease as spores can overwinter on crop trash and on weeds. Losses from this disease can be severe, therefore monitoring throughout the season is extremely important since this disease can move into large areas very quickly when conditions are optimal. Irrigation management is important as the disease develops quickly in high humidity situations. Plant and climate based models have been effective in forecasting the presence of late blight; control actions should be taken when the pathogen is present in an area and disease conditions are favorable. Growers know that preventive measures are necessary as there are no curative fungicides.

<u>Bacterial speck</u> (*Pseudomonas syringae* pv. tomato) – Varieties resistant to race 0 of this disease are available. Delaying plantings until weather is warm and dry will limit disease development. Seed treatments and copper are very effective preventative controls for this disease. Proper greenhouse management of transplants is one of the most the important means to limit problems with this disease. A copper/Mancozeb (Dithane) combination is also good, however, there are some restrictions concerning Dithane use since ethylene bisdithiocarbamate (EBDC) has reportedly shown up in ground water.

<u>Stem Botrytis</u> (*Botrytis* spp.) is a disease that is mainly controlled through proper sanitation in the greenhouse and planting transplants as soon as possible after delivery.

<u>Additional Information on Controls</u>

Cultural Control: There are a number of practices that can be used by growers to minimize risk from plant disease, such as using fields with good drainage and planting into high beds. Additional controls include: crop rotation, irrigation management, avoiding use of sprinklers in early spring or after early fruit development, proper fertilization (excessive nitrogen should be avoided), minimizing soil compaction, and good management of greenhouse plants.

Biological Control: Promot Plus (*Trichoderma*) and compost teas are reported to be somewhat effective in controlling Pythium, Fusarium, and Rhizoctonia when applied as a seed treatment or a potting medium drench.

New Technology: None reported.
New Chemistry: None reported.

A "TO DO" List for Management of Early Season Diseases in Tomatoes:

Research:
1) Evaluate Messenger for bacterial speck control in greenhouse and field use and benzothiadiazole (Blockade), a plant activator fungicide.
2) Improve/develop seed assays for pathogen screening.
3) Evaluate disease resistance development.

Regulatory:
Clarify label language that includes greenhouse, field, and greenhouse plants for transplant production as to what can or can not be done with a material.

Education:
Educate greenhouse growers and transplant providers on disease identification and management, especially irrigation management.

Nematodes

Root knot nematode (*Meloidogyne incognita)* is the major species of nematode of economic importance to tomato production in California, although the closely related *M. javanica* may be present in some areas. High numbers of nematodes may build up in light texture soils where significant crop loss can be expected in susceptible host plants. Nematodes cause a plant to develop shallow root systems that are unable to meet the great evapotranspiration demands brought on by hot temperatures.

Soil sampling and a knowledge of the history of a particular field will help to determine what preventative treatments need to be made to control this pest. Nematode resistant tomato varieties, crop rotation, and soil solarization are non-chemical techniques to prevent or reduce high numbers of nematodes in the soil.

There are a number of non-chemical nematode control options for California tomato producers. Resistant varieties and crop rotation are good cultural techniques to reduce nematode populations in the soil and to avoid crop damage. Soil solarization provides only fair control to within shallow depths and there are overlying economic concerns with using this technique because it takes field out of crop production. The use of cover crops and leaving fields fallow can be effective, but these option are not always economically feasible given the cost of land and the price of the commodity. Chitin, a biological method to control nematodes, has been reported to be erratic in control, takes a large amount of material and can be costly.

Several nematicides or soil sterilants with a range of efficacy are available for nematode control. Metam-sodium (Vapam) provides good to fair control. Methyl bromide can be very effective; however, the use of this material is being phased out. Dichloropropene (1,3-D or Telone) provides good to fair control; however, township cap limits on the use of this product might be prohibitive to its use. Oxamyl (Vydate) provides only fair control of rootknot nematodes.

Additional Information on Controls

Cultural Control: No new techniques reported.
Biological Control: No new techniques reported.

New Technology: No new techniques reported.
New Chemistry: Iodomethane.

> A "TO DO" List for Management of Nematodes in Tomatoes:
>
> Research:
> 1) Development of nematode resistant varieties.
>
> 2) Evaluate *Brassica* incorporation and solarization impact on nematode populations.
>
> Regulatory:
> Register Iodomethane for nematode control.
>
> Education:
> The California industry needs to communicate to seed providers that rootknot nematode resistance should be in all varieties.

Pests during Flowering and Fruit Development

Insects and Mites

The value of fresh market tomatoes is entirely dependent upon the quality of the crop and as a consequence of this, very little cosmetic damage can be tolerated. Insecticides are used on about 79% of all tomatoes grown in California and treatments are applied as foliar applications. The primary pests targeted by these treatments include stink bugs, aphids, whiteflies, thrips, leafminers, mites, beet armyworm, tomato fruitworms, and pinworms. Care must also be taken to monitor pests regularly and avoid secondary pest outbreaks, which arise from insecticide treatments.

These pests are controlled with standard insecticides such as organophosphates and carbamates, however, newer chemistries have also been shown to be effective. Imidacloprid (Admire and Provado) and spinosad (Success) are newer reduced risk compounds which are showing great promise. *Bacillus thuringiensis* (Bt) is a widely used microbial insecticide and pheromones used as population monitoring tools and as mating disruptants are effective tools. Insecticidal soaps (M-Pede) have only been moderate in their level of effectiveness and this material is most effective when used on nymphs. Parasites, predators, and naturally occurring viruses have shown limited impact on high insect densities. Unfortunately, biological control has generally not been shown to be a commercially viable treatment option for many pest species present in fresh market tomatoes. Due to the high value of the fruit and the low tolerance of damage by consumers, care must be taken to intensively manage insect damage using an integrated approach. Integrated Pest Management in tomatoes thus incorporates many tactics, with great care given to decisions on which pesticides might be needed, since secondary pests can be very problematical in this crop.

Stink Bugs are a serious threat to fresh tomatoes, especially in the Merced region of Area I. Consperse stink bug (*Euschistus conspersus*), southern stink bug (*Nezara viridula*), Says stink bug (*Chlorochroa sayi*), and several other species are considered by PCAs to be among the hardest insect species to control. Methamidophos (Monitor) provides good to excellent control of this very migratory pest. Endosulfan (Thiodan) also provides good to excellent control, however there are concerns with this material getting into the waterways and the use of this product is very restricted with buffer zones limiting its use in Areas I and II. Permethrin (Pounce) is registered, however this, like esfenvalerate (Asana) only provides poor control of stinkbugs and tends to flare secondary pests. Dimethoate and Potash soap (M-Pede) only provide poor to fair control of this pest.

Aphids can be a problem in the main season by direct feeding damage and as a vector of viral diseases. Potato aphids (*Macrosiphum euphorbiae*), green peach aphids *(Myzus persicae*), and cotton/melon aphids (*Aphis gossypii*) can be a problem in most years. Biological control by ladybird beetles (ladybugs) and green lacewings can be seen at times in great numbers in tomato fields, but these beneficial usually only get to sufficient densities once significant damage has been sustained by the crop. For this reason, biological control has only been relied upon to a very limited degree in fresh market tomato production. Azadirachtin (Neem oil), a material approved for use in organic systems, only provides poor control of aphids.

Dimethoate works fair to good for aphids, however, it is hard on parasites. Pymetrozine (Fulfill) is a good aphicide while imidacloprid (Provado and Admire) work well, but cannot be used late in the season because of PHI issues. Oxamyl (Vydate) provides good control as a drip irrigation application. Success (Spinosad) only provides poor to fair control of aphids. Methomyl (Lannate) is used with only poor to fair results and resistance has been reported with green peach aphids. Methamidophos (Monitor) is only moderately effective on aphids.

Whiteflies can be a pest problem during flowering and fruit development stages. The silverleaf whitefly, *Bemisia argentifolii*, and the greenhouse whitefly, *Trialeurodes vaporariorum* represent species that have to be monitored throughout the season. Pyriproxyfen (Knack), an insect growth regulator (IGR), provides very good control of whiteflies but pre-harvest interval (PHI) issues preclude the use of this material at certain times of the season. Imidacloprid (Admire) also works and has PHI issues. Imidacloprid (Provado) is effective, but may be disruptive to beneficials, especially parasites. Fenpropathrin (Danitol) and methomyl (Lannate) tank mixes along with oxamyl (Vydate) only provide fair control of pests, while azadirachtin (Neem oil) is reported to provide poor control of this pest. Areawide crop scheduling is extremely important, particularly in desert growing regions where continuous cropping can provide "bridges" to new host material and whitefly buildup has been observed to be extreme.

Western Flower Thrips (*Frankliniella occidentalis*) can be managed with a fairly new material named spinosad (Success), which provides very good control, although there is no residual activity. Imidacloprid (Admire) offers some control of thrips but Admire has PHI issues. Imidacloprid (Provado) is also effective, and its use has been reported to be soft on beneficial species, especially parasites. Azadirachtin (Neemix) is reported to only provide fair results for thrips control. Pyrethroids (such as Asana) can create leafminer flare-ups, so these materials are used judiciously. It is important to manage pesticide resistance when treating for thrips and the use of monitoring fields and adjacent vegetation is important. Weed control around the field is also important in reducing problems brought about by thrips. Early detection and removal of affected plants is effective in certain areas, especially in southern production regions.

<u>Leafminers</u> (*Liriomyza trifolii, L. sativa,* and *L.huidobrensis)* can cause considerable damage to tomato leaves as the small, dipteran fly larvae tunnel into leaf tissue. Leafminers have been a problem in southern growing regions. You will generally not have a flare-up with leafminers if you can avoid killing parasites when treating for other pests. Abamectin (Agri-Mek) and cyromazine (Trigard) provide good to excellent control with low impacts on beneficial insect species. Spinosad (Success) provides good to fair control of leafminers.

<u>Mites</u> have eight legs and therefore are not classified as insects, which have six legs. Tomato russet mites (*Aculops lycopersici*) often blow into a field from neighboring areas. Two-spotted spider mites (*Tetranychus urticae)* are another mite species that can impact on tomatoes. Mites feed on the stems and leaves of tomato plants. Predatory mite releases are effective biological control agents when mite population densities are low to moderate. Continued releases are necessary to keep populations in check. Controlling dust in and around fields reduces the tendency for mite hot spots to develop. Sulfur is the primary control measure used for mite control including organic production sites. Sulfur is more effective on russet mites as compared to spider mites. Dicofol (Kelthane) and abamectin (or avermectin marketed as Agri-Mek) provide excellent control of spider mites though abamectin (Agri-Mek) is not as effective for russet mites.

<u>Beet armyworm</u> (*Spodoptera exigua*) can inflict damage to developing tomato fruit. Methomyl (Lannate), permethrin (Pounce), and esfenvalerate (Asana) all provide good to excellent control of beet armyworms but may cause leafminer problems if applied early in the season. Indoxacarb (Avaunt) provides excellent control if applied early and by ground to ensure coverage; if used later in the season, aerial applications only provide fair control. Tebufenozide (Confirm) is a good material for beet armyworm and *Bacillus thuringiensis* (Bt) applications if used at flowering can help to suppress populations. Spinosad (Success) has been used with only fair results and performance does not seem to be very consistent on this harder to control lepidopteran species, but this product is still a good choice in a rotational program to manage resistance.

<u>Tomato fruitworm</u> (*Helicoverpa zea)*, formerly known as *Heliothis*, is a major threat to developing fruit when fruit size is about one-inch in diameter. Methomyl (Lannate), permethrin (Pounce), and esfenvalerate (Asana) all provide good to excellent control of tomato fruitworms but may cause leafminer problems if applied early in the season. Indoxacarb (Avaunt) provides excellent control if applied early and by ground to ensure coverage; if used later in the season, aerial applications only provide fair control.

<u>Tomato Pinworm</u> (*Keiferia lycopersicella)* can become a problem in some production regions. The primary tactic for pinworm control is through pheromone disruption. This has been used with excellent results. Abamectin (Agri-Mek) provides good control of pinworms; while methomyl (Lannate) is only fair on this species.

Cabbage Looper (*Trichoplusia ni)* has become a problem in the San Joaquin Valley (Areas I and II). Like control of beet armyworm in tomatoes, methomyl (Lannate), permethrin (Pounce), and esfenvalerate (Asana) all provide good to excellent control of cabbage loopers, but may cause leafminer problems if applied early in the season. Indoxacarb (Avaunt) provides excellent control if applied early and by ground to ensure coverage; if used later in the season, aerial applications only provide fair control. *Bacillus thuringiensis* (Bt) applications can help to suppress looper populations. Spinosad (Success) has been used with only fair results but this product is good to use in rotational programs for resistance management.

Tomato Psyllid (*Paratrioza cockerelli)* is a fairly new pest that has entered the southern production regions (especially Area IV and the production region in Baja California). The pest can be very damaging to tomato crops as it feeds on the underside of leaves. Best management practices and adequate controls for this pest are not known at this time; UC entomology research has already been started. Imidacloprid (Admire) used at planting in the desert region (Area V) has been reported by a PCA to offer some control of psyllids.

Beet leafhoppers (*Cirulifer tenullus*) can be pests throughout the growing season so this species should be monitored the entire season as it is the vector for curly top virus. Methomyl (Lannate) provides good control, but it has very short residual activity and there are other more effective alternatives such as imidacloprid (Admire). Malathion is the product effectively used in the state regulatory program for this pest. Fallow field management is an effective means to manage infestation levels in tomato fields, however there are economic concerns with leaving a field out of production.

Hornworms (*Manduca quinquemaculata*) are rarely encountered in sufficient numbers to become a problem in tomato fields as sprays aimed at more damaging moth species such as fruitworms or armyworms control hornworms too. Methomyl (Lannate), permethrin (Pounce), and esfenvalerate (Asana) provide good to excellent control of hornworms, but may cause leafminer problems if applied early in the season. Indoxacarb (Avaunt) provides excellent control if applied early and by ground to ensure coverage; if used later in the season, aerial applications provide only fair control. *Bacillus thuringiensis* (Bt) applications can help to suppress hornworm populations, especially small larvae. Spinosad (Success) has been used with only fair results but this product is good to use in rotational programs for resistance management.

Western Yellow Striped Armyworm (*Spodoptera praefica* and *S. ornithogalli)* can attack developing tomato plants and gouge into the developing fruit. Methomyl (Lannate), permethrin (Pounce), and esfenvalerate (Asana) all provide good to excellent control of armyworms but may cause leafminer problems if applied early in the season. Indoxacarb (Avaunt) provides excellent control if applied by ground to ensure coverage; if used later in the season, aerial applications only provide fair control. Tebufenozide (Confirm) is a good material for armyworms while *Bacillus thuringiensis* (Bt) applications if used at flowering only marginally suppress populations, even with small instar larvae.

Additional Information on Controls

Cultural Control: no new techniques reported.
Biological Control: no new biocontrols reported, use remains limited due to efficacy.

New Technology: pheromone technology has been very effective.
New Chemistry: neonicotinoids.

A "TO DO" List for Management of Insects in Established Tomatoes:
<u>Research</u>: 1) Evaluate alternative controls and monitoring techniques for Stink bug. 2) Develop new controls for Whiteflies (especially greenhouse whiteflies). 3) Study Psyllid biology, monitoring, and control. 4) Continue Genomics research program with UC BioStar. 5) Develop resistance management programs for all insect pests. 6) Evaluate the non-target effects of new compounds. 7) Develop insect resistant tomato plants.
<u>Regulatory</u>: 1) Obtain California registrations for the neonicotinoids. 2) Change Pre-harvest interval (PHI) for Pyriproxyfen (Knack) from 14 days to 7 days with an actually preferred target PHI of 3 days.
<u>Education</u>: 1) Develop training on using Pheromone trapping for monitoring. 2) Provide training on crop free periods for whitefly control. 3) Provide training on resistance management programs across borders (state and federal).

<u>Weeds</u>

The most difficult weed species to manage in tomatoes are nightshades, field bindweed, nutsedges, annual grasses, and dodder. Most registered herbicides are ineffective and hand labor is required to manage many of these species. New herbicides are showing great promise for weed control in tomatoes. Cultivation is used to control weeds up to the time of "layby." Layby is considered the stage of tomato growth when cultivation equipment cannot be used anymore; 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.

<u>Black nightshade</u> (*Solanum nigrum*) and <u>hairy nightshade</u> (*S. sarrachoides*) are in the same botanical family as tomato. Most tomato herbicides are not effective against nightshades. Hoeing and cultivation are non-chemical options for control of these difficult weeds. Metribuzin (Sencor) and rimsulfuron (Shadeout) are effective herbicides, as well as EPTC (Eptam) and acetamide (Dual MAGNUM), which are used as layby treatments. Metolachlor or Acetamide (Dual MAGNUM) is also used in direct seeded plantings but it has a 90-day PHI. Soil covering with plastic is a non-chemical option but expensive costs associated with materials and labor limit its use.

<u>Field bindweed</u> (*Convolvulus arvensis)* and <u>purple nutsedge</u> (*Cyperus rotundus*) are very difficult weed species to control. Only cultivation and hoeing are options for these weeds in established tomatoes.

Yellow nutsedge (*Cyperus esculentus*) is also a difficult species to control but halosulfuron (Sandea) is now registered for use on this weed. Post-plant applications of metolachlor (Dual Magnum) in directed sprays will also provide some weed control.

Annual grasses - Hoeing and cultivation are non-chemical options for control of grasses. Irrigation management also is an aid to managing several grass species. Sethoxydim (Poast) and clethodim (Prism) are effective grass herbicides.

Dodder (*Cuscuta* spp.) is difficult to control in established tomatoes. Only hoeing, flaming, or rotating crops provide any control of this parasitic weed. The herbicides DCPA and rimsulfuron (Matrix) are reported to suppress this weed.

Velvetleaf (*Abutilon theophrasti*) can be a problem weed in established tomatoes. Hoeing, hand removal, and cultivation are non-chemical options for control of velvetleaf. Metribuzin (Sencor) and rimsulfuron (Shadeout) are effective herbicides, but applications need to be made when weeds are small (< 2inches tall).

Lambsquarters (*Chenopodium album*) and nettleleaf goosefoot (*Chenopodium murale*) weed control options include cultivation and hoeing in established tomatoes. If either of these weed species were present prior to layby, growers would have had several herbicide options available to control them. In that case, it could be expected that the field would be treated with herbicides instead of incurring high labor charges for hoeing later in established tomato fields.

Common Purslane (*Portulaca oleracea*) can be controlled by cultivation and hoeing in established tomatoes. Rimsulfuron (Shadeout) provides fair to good control and EPTC (Eptam) and trifluralin (Treflan) are used as layby treatments in direct seeded tomatoes. Pebulate (Tillam) is also used in direct seeded tomatoes when the plants are 6 – 8 " tall.

Additional Information on Controls

Cultural Control: No new techniques reported.
Biological Control: No new techniques reported or commercially available.

New Technology: No new products reported.
New Chemistry: Halosulfuron (Sandea).

A "TO DO" List for Weed Management in Established Tomatoes:

Research:
1) Develop control measures for black and hairy nightshade.
2) Develop control measures for field bindweed.
3) Develop control measures for nutsedge.
4) Develop control measures for dodder.

Regulatory:
1) Ease 8-month plant-back restrictions on halosulfuron (Sandea) for tomato transplants.

2) Ease plant-back restrictions on metolachlor (Dual MAGNUM) as well as restrictions on different rates for soil types (sometimes listed as acetamide).
3) Expedite the registration of pendimethalin (Prowl).

Education:
Educate growers on use of halosulfuron (Sandea) and pendimethalin (Prowl).

Diseases

Fungicides are used on approximately 80% of the fresh market tomatoes grown in California. Fresh market tomatoes generally receive 1.5 to 2 fungicide treatments per year, with the majority applied as foliar treatments. The major diseases, which occur, include *Verticillium*, *Sclerotinia*, late blight, powdery mildew, *Phytophthora* root rot, black mold, *Botrytis* gray mold, bacterial speck and bacterial spot . Viruses are a problem in many areas and these are vectored by insects such as thrips, aphids, and whiteflies. Vector control has not been a good strategy to manage disease incidence. Specific viruses of importance include curly top, yellow top, alfalfa mosaic, tomato spotted wilt virus, tomato infectious chlorosis virus (TICV) and tomato chlorosis virus (ToCV).

Verticillium/Fusarium wilt diseases– Growers and PCAs have reported the use of aerially applied foliar nutrients to maintain and develop plant canopies, hoping to reduce the incidence of these diseases. Some researchers believe that growers attempt to reduce plant stress to control these pathogens after noticing a problem. This may be another research topic to verify results as variety resistance, crop rotation, and fumigation are typically considered the management options. The use of cover crops or organic amendments may help control these pathogens but this topic hasn't been identified as a top priority for a research program with limited funds.

White mold (*Sclerotinia sclerotiorum)* disease infection can be caused by both air-borne ascospores and soil-borne sclerotia. Therefore, deep plowing and crop rotations have limited use as a control strategy. For growers with subsurface drip irrigation, irrigation management that keeps the surface of the topsoil dry can be very effective in reducing the incidence of this disease in established tomatoes (21).

Late blight (*Phytophthora infestans*) – chlorothalonil (Bravo), mancozeb (Dithane)/maneb, and azoxystrobin (Quadris) are used as preventive materials, however, these fungicides do not control late blight once the disease is present (no curative action). Metalaxyl (Ridomil) is not used in California due to resistance issues (see Table 28). Propamicarb hydrochloride (Prevacur Flex) works well but is not currently registered as its use was previously under a Section 18. A new product, pyraclostrobin (Cabrio) has recently been registered for use in 2003. Disease forecasting is a used tool to time preventive treatments of fungicides to control late blight. The registration status of dimethomorph (Acrobat) has been established and it is now available as a preventive treatment. Resistance management is a critical area in controlling late blight as strains can mutate quite rapidly.

Powdery mildew – azoxystrobin (Quadris) only works poor to fair; labeled rates may be too low. Myclobutanil (Rally) provides fair preventative control of powdery mildew; sulfur is only fair to poor in performance. Growers and PCAs are encouraged to rotate the above mentioned materials as resistance management of mildew is becoming a bigger problem. Trifloxystrobin (Flint) is registered but its use should be rotated with materials that are not in the same class of fungicides. Pyraclostrobin (Cabrio) has recently been registered so usage patterns will be seen in 2003. Systemic Acquired Resistance (SAR) type products (e.g., Messenger, a harpin protein) may help plants to sustain or resist infection by this disease but research is needed to verify this. Disease forecasting is an effective tool to time preventative treatments of fungicides to control powdery mildew. Research is currently underway through the UC to study powdery mildew and identify new management strategies.

Phytophthora root rot – Water management is the best way to manage the onset of this disease in established tomatoes. Metalaxyl (Ridomil) provides fair to good control of Phytophthora root rot. Aluminum tris (Aliette) is only rated poor to fair for control of this disease.

Botrytis gray mold – chlorothalonil (Bravo) provides good control of this disease.

Bacterial speck (*Pseudomonas syringae*) and Bacterial spot (*Xanthomonas campestris*) are favored by cool and wet conditions. Therefore, irrigation management and avoiding sprinkler irrigation that brings moisture onto the leaf surfaces are helpful in reducing problems with these diseases. Various copper formulations in combination with mancozeb (Dithane) or maneb are effective.

Viruses

A wide variety of viruses are found in tomatoes including curly top, yellow top, alfalfa mosaic, cucumber mosaic, tobacco mosaic, potato Y in the potyvirus group, tobacco etch, tobacco streak, and others. Only resistant tomato varieties are effective in reducing the incidence of these viral diseases as insecticide applications aimed at the vectors are not adequate in stopping the disease transmission. In the South Coast area, removing infected plants from the field by hand appears to slow the incidence of and spread of spotted wilt virus. This method of roguing plants would not be as effective for TICV, however, since symptoms of this virus take much longer to develop. TICV can be widely dispersed in the field by the time symptoms begin to appear on the earliest infected plants. Vector control (e.g., thrips, aphids, and whiteflies) has been met with little or no success for reducing virus problems in established tomatoes.

Additional Information on Controls

Cultural Control: Irrigation and fertilizer management are effective for some diseases.
Biological Control: No new products are commercially available.

New Technology: Systemic Acquired Resistance products such as harpin proteins.
New Chemistry: Strobilurins are new and effective, but resistance management is key.

A "TO DO" List for Disease Management in Established Tomatoes:

Research:
1) Develop new broad-spectrum fungicides.

2) Conduct field fungicide trials on late blight with dimethomorph (Acrobat) and an unregistered combination of materials famoxadone and cymoxanil (Tanos).
3) Conduct field trials on powdery mildew , evaluate other fungicides and plant resistance activators.
4) Develop predictive models based on detection of viral inoculum in weeds and presence of insect vectors.
5) Validate late blight and powdery mildew models.
6) Develop varieties resistant to Verticillium Race II and *Fusarium.*
7) Develop methyl bromide alternatives.
8) Evaluate the effect of cover crops on disease.
9) Develop virus resistant cultivars.

Regulatory:
1) Evaluate the long-term viability of the curly top control program.
2) Expedite the registration of Propamicarb hydrochloride (Previcur Flex) fungicide for use in California.

Education:
No needs reported at this time.

Vertebrate Pests of Fresh Tomatoes

Voles (meadow mice), gophers, rabbits, and squirrels may cause problems to a tomato crop, especially along field borders. These pests can do direct damage to the harvestable crop, or they may interfere with normal irrigation and cultural activities. There are several non-chemical techniques to discourage these pests including prevention, habitat management (i.e., weed) glue boards, baiting, trapping, and exclusion. Poison baits and pellets are registered for some of these pests and can be highly effective.

Birds are serious pests of tomato fields and the only effective control strategy to reduce 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. The use of Mylar tape strips attached to solid set sprinkler pipes or risers in the field has had very limited success with horned larks. With the extensive use of transplants, vertebrate pest damage usually occurs later in the season. 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.

Larks, deer, and pheasants are not a problem in transplanted tomatoes. Foxes and coyotes do not damage the crop directly, but damage the drip tape interfering with proper irrigation.

Noise is the only tool that helps with bird control. Lethal control is needed for birds, especially crows. Voles were formerly controlled with diphacinone (Ramik Green). The registration status of this product needs to be clarified. Lethal control works well for squirrels and is also available for gophers (phosphine gas). Bait stations only work fairly well for a number of vertebrate pests including voles, gophers and squirrels. Coyotes and foxes are only partially controlled by trapping.

Additional Information on Vertebrate Control in Tomatoes

Cultural Control: No new techniques reported.
Biological Control: None available.

New Technology: Air blast equipment.
New Chemistry: No new techniques or products reported.

A "TO DO" List for Vertebrate Control in Tomatoes:

Research: No needs reported at this time.

Regulatory:
1) Obtain consistency of issuance of depredation permits.
2) Need to determine status of several formerly used lethal controls.

Education:
Provide grower updates on vertebrate pest control options.

Plant Growth Regulators

The Plant Growth Regulator Ethephon (Ethrel) is sometimes used as a ripening agent for fresh market tomatoes. Approximately 6% of the crop was treated with PGR's for this purpose (2,458 acres in 2000) This ripening agent acts as a plant growth regulator to hasten or accelerate fruit ripening. Ethephon will not ripen immature green fruit. Ethylene treatment in storage facilities is common for uniform color development.

Additional Information on Plant Growth Regulators in Tomatoes

New Technology: No new techniques or products reported.
New Chemistry: No new techniques or products reported.

A "TO DO" List for Plant Growth Regulators in Tomatoes:

Research: No requests at this time.
Regulatory: No requests at this time.
Education: No requests at this time.

Fruit Maturity and Harvest

Fields are ready for harvest once they have met the approved standards according to a legal maturity index. Tomatoes may be harvested when they are green, pink, or red in color. A minimum harvest maturity is defined according to color, internal seed development, and gel formation within the locules. Tomato quality is primarily based on uniform shape and the absence of injury or handling defects. Firmness is also a component of quality. Size is not a factor of grade quality, but may strongly influence commercial quality expectations.

Post-Harvest Diseases

Tomatoes are sensitive to many environmental and genetic disorders, which may develop during post-harvest ripening or storage. Fertilizer and irrigation management, weather conditions, insect feeding injury, asymptomatic virus infection, and unknown agents may all interact to affect post-harvest quality.

Diseases are an important source of post-harvest loss depending on season, region and handling practices. Common organisms responsible for post-harvest decay or surface lesions include the fungal pathogens Black Mold Rot (*Alternaria*), Gray Mold Rot (*Botrytis*), Sour Rot (*Geotrichum*), and Hairy Rot (*Rhizopus*). Bacterial Soft Rot (*Erwinia*) can be a serious problem particularly if proper harvest and packinghouse sanitation is not monitored closely.

Treatment with hot air or hot water immersion has been effective in preventing surface mold but has not been used extensively for commercial treatments. Controlled atmospheres (CA) can be effective in delaying fungal growth on the stem-end and fruit surface.

The following organisms (disease) can cause post-harvest losses in fresh market tomatoes:

- *Alternaria* (Black Mold Rot)
- *Botrytis* (Gray Mold Rot)
- *Geotrichum* (Sour Rot)
- *Rhizopus* (Hairy Rot)
- *Erwinia* spp. (Bacterial Soft Rot)

These diseases are generally controlled with a hot water bath. Post-harvest losses can be reduced for fall tomatoes by waiting for daytime temperatures to warm up and to pick and pack when the fruit is not wet.

Additional Information on Post-Harvest Disease Control in Tomatoes
Cultural Control: No new techniques reported.
Biological Control: None available.

New Technology: No new techniques reported.
New Chemistry: No new techniques or products reported.

A "TO DO" List for Post-Harvest Disease Control in Tomatoes:

Research: Need to develop safe and effective post harvest chemicals and techniques with cost analysis.

Regulatory: Government should provide or conduct post-harvest residue testing (take this burden off of growers).

A "TO DO" List for Post-Harvest Disease Control in Tomatoes:

Education:

Educate growers on ***best management practices*** since this impacts post-harvest quality more than any other thing.

Food Safety

Food borne illnesses associated with fresh produce consumption have been an increasing occurrence. Sources of microbial contamination include soil, water, manure, fertilizer, air, equipment, and produce handlers. Produce is exposed during transportation, cooling, packing, storage and secondary handling.

Prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred. Microbial contaminants of potential or perceived concern in fresh market tomatoes include *Salmonella* spp., *E. coli, Geotrichum* spp., *Listeria* spp *, and Pseudomonas* spp. Current techniques and products used to minimize contamination include: prevention, field sanitation, chlorinated water baths, using clean processing water and proper cooling, worker hygiene, clean packing facilities and transportation. Traceback mechanisms are in place, however this system breaks down after receivers ship the produce and boxes are broken down (commingling occurs).

A "TO DO" List for Food Safety Issues in Tomatoes:

Research: No needs reported at this time.

Regulatory: No new registrations or regulatory issues at this time.

Education:
1) Train workers on the value to keeping packing facilities clean.
2) Develop a communications plan to assure consumers that California fresh tomatoes are safe to eat.
3) Develop a training program for food service handlers, with a special emphasis on cut fruit.

International Trade and Export Issues

Approximately 20% of all California fresh tomatoes are exported, with primary destinations being Canada, Mexico, and Japan. While some recent movement towards establishing international tolerances (MRLs = maximum residue levels) for pesticides has been discussed in recent years by the EPA, significant progress towards harmonizing regulatory standards with other countries has not been made. In North America, the NAFTA Technical Working Group on Pesticides has started to convene on these issues. As world food sources are more globally sourced, our own regulatory agencies, US-EPA, USDA, and FDA and their foreign counterparts must address food safety with regard to pesticide residues.

The Codex Alimentarius Commission was created by two United Nations organizations in 1962. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) serve as the major international mechanisms to encourage trade in food while promoting the health and economic interests of consumers. The US Codex Office is located in the Food Safety and Inspection Service at USDA in Washington, DC.

Presently it takes approximately 8 years to obtain an MRL through the Codex system. This is problematical in that while the Food Quality Protection Act of 1996 encourages the US grower community to move towards reduced risk compounds, an international registration for these materials may lag behind for several years. It is unclear at this point as to how this situation will be handled once a crisis arises, however commodities which increasingly deal with exports must address this issue as soon as possible.

- Current export markets are: Canada, Japan, and Mexico
- Future potential export markets include: Central America, Chile, Indonesia, Hong Kong and China

A "TO DO" List for International and Export Issues in Tomatoes:

Research: No needs reported at this time.

Regulatory: Insure that all new pesticides registered for fresh tomatoes are within NAFTA and Codex provisions in advance of trade opportunities.

Education: No needs reported at this time.

Critical Pest Management Needs for the California Fresh Tomato Industry

Listed in order or importance, the following list highlights those issues that have been identified as critical to the viability of the fresh market tomato industry in California.

Research Priorities: Finding practical solutions to insect control are of immediate and serious concern to producers of fresh market tomatoes in California.

1) Of paramount importance is the need to find effective alternatives to rotate with methamidophos (Monitor) for stink bug control.
2) Vector biology/disease management. (whiteflies/infectious virus, leafhoppers/curly top, thrips/TSW, aphids/Poly viruses, and psyllid/yellows).
3) Develop alternatives to rotate with organophosphates and carbamates for soil pests.
4) Development of pest resistant tomato varieties needs to be encouraged, advanced, and incorporated into existing seed development research. Plant breeding research should find and develop new tomato varieties that are resistant to the many plant diseases and insect pests that are problems.
5) Develop new technologies and techniques to manage field bindweed, nutsedge, and nightshade.
6) Develop a systems approach to low input pest control in tomatoes
7) Develop safe and cost-effective post harvest disease controls.

Regulatory Priorities: The most important action that needs to be done involves an enhanced interaction between Cal-EPA and US-EPA. Harmonization should be encouraged to facilitate and hasten the concurrent registration of reduced risk products. Concurrent registrations need to be brought into California in a more timely manner to eliminate the disadvantage that occurs when new materials get registered first in other states.
In terms of specific registrations, the fresh tomato industry needs:
1) New products registered to rotate with methamidophos (Monitor) for stink bug control and to prevent insect pest resistance,
2) New chemistries for late blight and powdery mildew control and overall disease resistance management,
3) Clarify label issues for imidacloprid (Admire) use in greenhouse transplants.

Educational Priorities:

1) Educate government agencies on unfair trade/cultural practices, which result from regulatory burdens.
2) Educate regulators and consumer groups on IPM and cultural practices, especially as this information relates to risk assessments for crop protection tools.
3) Educate the general public on how IPM is used in agriculture and the impact of FQPA on the cost of food.
4) Identify crops and production areas where a crop free period could be implemented for grower education of area-wide pest management.
5) Continue emphasis on the “5 a Day” and “Buy California” Programs.

IR-4 Project Information Relative to California Fresh Market Tomatoes

The following table summarizes the IR-4 status for registration and research issues of importance to the California tomato industry. Project requests will be made to IR-4 through Pesticide Clearance Request (PCR) forms. Only compounds that have been identified by manufacturers to be possible materials for registration have been listed.

Table 2

Short term critical needs	Stink Bug materials – alternatives to methamidophos (Monitor)
Long term needs	Powdery mildew and late blight materials, herbicides to control nutsedge and morningglory
Priority **A**	**Bifenazate** (mites); petition in preparation; submission expected 2002 **Bifenthrin** (whiteflies, mites, thrips, aphids) (GH use); petition under review with the manufacturer **Buprofezin** (whitefly); (GH use); trials done in 2001 **Captan** (soil pathogens); for all vegetable transplants, tomato and lettuce representative crops in progress 2002 **Carfentrazone-ethyl** (weeds);field work 2001 **Cyprodinil + Fludioxonil** (Botrytis, powdery mildew) field trials 2002; (7 trials in Region 10) **Fenhexamid** (Botrytis); Field work done '99,'00,'01 **Pyriproxyfen** (whiteflies, aphids, fungus gnats, shoreflies) field work (GH) done in '00, '01, '02 **Rotenone** (CPB, stink bugs) field work done in '98; currently ai is under reregistration review **Uniconazole** (controlling transplant height); 2002 trials (7 in Region 10)
Priority **B**	**Abamectin** (rootknot nematodes); MB alternative, suppression only; tolerance established but confirmatory residue data needed for label **Acequinocyl** (aphids, leps, thrips, leafminers); researchable project **BAS 500** (early blight, Botrytis, Septoria, powdery mildew, black mold) MFG doing residue work, need IR-4 efficacy in 2001. **BAS 510** (early blight, Botrytis, Septoria, powdery mildew, black mold) MFG doing residue need efficacy IR-4 efficacy in 2001. **BAS 516** (early blight, Botrytis, Septoria, powdery mildew, black mold) MFG number 516 is supported by 500 and 510. **BAS 516** (Botrytis, Pythium) (GH) MFG assist with residue. **Bifenazate** (spider mites) (GH) GH trials done in '01 **Bifenthrin** (whitefly, thrips) petition submitted to EPA 6/01 **Captan** (damping off, Rhizoctonia, Pythium); reregistration, petition in preparation (prepared 8/97) **Captan** (Rhizoctonia, Pythium) (GH); reregistration, petition in preparation (prepared 8/97); see above "A" priorities **Chlorothalonil** (GH) (*Botrytis cinerea*); tolerance established need confirmatory residue data. **Copper compounds** (bacterial diseases) MFG reregistration objectives **DCNA** (GH) (Botrytis, late blight, Sclerotinia) MFG doing field use. **Endosulfan** MFG reregistration objective **Fenhexamid** (gray mold, *Botrytis cinerea*) (GH) MFG providing data, IR-4 will submit the petition **Fenpropathrin** (aphids, mites, leps, thrips, whiteflies) use registered/ MFG label 9/95. **Flumioxazin** (weeds) MFG will assist with analysis. **Halosulfuron** (nutsedge) MFG objective **Hexythiazox** (spider mites) (GH) MFG data IR-4 to submit **Imidacloprid** (whitefly, aphids, thrips) (GH) petition submitted with EU data 6/00 **Lactofen** (nightshade) HOLD **Milbemectin** (aphids, thrips, whiteflies) researchable project **Milsana** (Botrytis, powdery mildew) confirmatory residue data needed
	Pendimethalin (grasses and broadleaf weeds) NOF 3/01 **Propamocarb-HCL** (Pythium root rot, damping off) Under evaluation **Pymetrozine** (aphids, whiteflies) (GH) MFG has concerns about GH use **Sulfentrazone** (weeds) need phyto data on direct seeded **TM443** (Penicillium, sour rot decays) under evaluation

	Ziram (anthracnose, early blight, gray leafspot), REREG petition under review
Priority **C**	**Chlorpyrifos** (lep larvae, mealybugs, thrips, leafminer) data submitted to MFG or state **Cyhexatin** (mites) HOLD (field and GH) **Dimethoate** (stinkbug, thrips, mites) rereg; MFG objective **Fomesafen** (broadleaf weeds) HOLD **Fosetyl-al** (Pythium damping off, Phytophthora root rot) (GH) under evaluation **Psuedomonas chlororaphis** (Pythium damping off, Phytophthora root rot, Fusarium crown rot) (GH) Under evaluation **Pyridaben** (mites) (GH) petition submitted 4/01 **Pyrimethanil** (botrytis) under evaluation **Rimsulfuron** (morning glory, ragweed, yellow nutsedge, lambsquarters, pigweed) ;Use registered (processing tomato only MFG?) **Thiophanate -methyl** (damping off) MFG will do analysis.

A "TO DO" List for Growers/IR-4 in Tomatoes:

Research Needs:

Evaluate the fungicide combination of cyprodinil and fludioxonil (Switch from Syngenta) on tomatoes.

Pesticide Clearance Request Forms Needed From Growers:

Sulfentrazone PCR

References

1) Agricultural Chemical Usage 2000 Vegetable Summary. Web address verified on March 6, 2002: http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/agcv0701.txt

2) California Irrigation Management Information System. Weather station database. Web address verified on March 10, 2002: http://www.cimis.water.ca.gov_

3) California Tomato Commission. Web site verified on March 10, 2002: http://tomato.org

4) *Compendium of Tomato Diseases.* Edited by J.B. Jones, J.P. Jones, R.E. Stall, and T.A. Zitter. American Phytopathological Society Press, 1991. St. Paul, Minnesota.

5) County Agricultural Commissioners' Data. August 2001. California agricultural statistics service. Web address verified on March 6, 2002: http://www.nass.usda.gov/ca

6) *Crop Profile for Fresh Market Tomatoes in California*. 2000. J.B. LeBoeuf, W.T. Lanini, E. Beckman, J. Farrar, and K. Farrar. Web address verified on March 6, 2002: http://pestdata.ncsu.edu/CropProfiles/docs/catomatoes-freshmarket.htm

7) *Crop Protection Reference - Labels and MSDSs.* C&P Press, New York. Web address verified on March 6, 2002: http://greenbook.net/ASP/free.asp

8) *Crop Time Line for Fresh Market Tomatoes in California*. 2002. J.B. LeBoeuf. Web address verified on June 10, 2003: http://www.pmcenters.org or http://pestdata.ncsu.edu/croptimelines/

9) *FDA Glossary of Pesticide Chemicals*. US Food and Drug Administration. Center for Food Safety and Applied Nutrition. Updated Oct. 2001. Web address verified on October 28, 2002: http://www.cfsan.fda.gov/~frf/pestglos.html

10) *Fresh Market Tomato Production in California.* 2000. Publication 8017. M. Le Strange, W. Schrader, and T. Hartz. Web address verified on March 6, 2002:http://anrcatalog.ucdavis.edu/pdf/8017.pdf

11) *Integrated Pest Management for Tomatoes.* Fourth Edition. F.G. Zalom et al. 1998. In UC DANR Publication 3274.

12) IR-4 Food Use Workshop – Priority Workshop Workbook for 2001 Projects. Fort Collins, Colorado.

13) Jones, H., J.M. Whipps, and S.J. Gurr. 2001. *The tomato powdery mildew fungus oidium neolycopersici.* Molecular Plant Pathology 2(6), 303-309.

14) Postharvest Technology, 3rd Edition. A. Kader, Technical Editor. 2002. UC DANR Publication 3311. Postharvest Technology Research and Information Center. Web address verified on March 6, 2002: http://postharvest.ucdavis.edu

15) Recommendations for maintaining postharvest quality. T.V. Suslow and M. Cantwell. Web address verified on March 6, 2002:
http://postharvest.ucdavis.edu/Produce/ProduceFacts/veg/tomato.htm

16) Sample costs to produce fresh market tomatoes. University of California Cooperative Extension. 2000. M. Le Strange, J.G. Valencia, R.J. Mullen, B. L. Weir, and K. M. Klonska. Web address verified on March 6, 2002: http://www.agecon.ucdavis.edu/outreach/crop/cost-studies/2000/freshtoms.pdf

17) Summary of pesticide use report data indexed by commodity. 1998-2000. California Department of Pesticide Regulation. Web address:verified on March 6, 2002:
http://www.cdpr.ca.gov/docs/pur/pur00rep/comrpt00.pdf

18) Summary of county agricultural commissioners' reports - Gross value by commodity groups - California 1999-2000. Web address verified on March 6, 2002:
http://www.nass.usda.gov/ca/bul/agecon/indexcav.htm

19) *The Importance of Pesticides and other Pest Management Practices in U.S. Tomato Production.* 1998. R.M. Davis et al. In National Agricultural Pesticide Impact Assessment Program Document Number 1-CA-98.

20) Thompson, Willard. MarketBuilder data search of methamidophos (Monitor) applications in California in 2000. 2002. http:/rinconpublishing.com

21) *UC IPM Pest Management Guidelines: Tomato.* F.G. Zalom et al. 2001. In UC DANR Publication 3339. http://www.ipm.ucdavis.edu

22) UC Vegetable Research and Information Center. Web address verified on March 6, 2002: http://vric.ucdavis.edu

23) USDA National Agricultural Statistics Service. Vegetable Acreage Summary. 2000. Web address verified on March 6, 2002: http://www.nass.usda.gov/ca/rev/veggies/101vegtb.htm

Appendices

Table 3

2000 California Tomato Statistics

FRESH MARKET TOMATOES

County	Harvest Acreage	Yield per Acre (Tons)	Production Tons/A	Price per Unit	Total Value in $
Contra Costa	43	19	816	880	718,000
Fresno	6,350	16.7	106,000	381	40,386,000
Imperial	547	20.9	11,405	460	5,246,000
Kern	3,240	19.4	63,000	364	22,963,000
Kings	431	19.1	8,232	346	2,848,000
Merced	11,500	14.2	162,941	498	81,136,000
Monterey	1,013	18.1	18,341	419	7,688,000
Sacramento	455	12.8	5,824	250	1,456,000
San Benito	272	12.1	3,283	403	1,323,000
San Diego	3,231	20.2	65,105	645	41,992,700
San Joaquin	8,880	11	97,700	496	48,414,000
Santa Clara	140	10.5	1,470	525	772,000
Stanislaus	2,100	16.2	34,000	324	11,020,000
Tulare	383	17.2	6,590	428	2,821,000
Sum of others	65				998,900
STATE TOTALS	38,650	AVG 15.15	584,707	AVG 460	269,782,600

Table 4 Cultural Activities Profile for California Tomatoes: NORTHERN SAN JOAQUIN VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep			■	■	■	■	■				■	
Transplant			■	■	■	■	■					
Seed												
Fertilization				■	■	■	■	■	■			
Thinning												
Irrigation				■	■	■	■	■	■	■		
Cultivation				■	■	■	■	■	■	■		
Harvest						■	■	■	■	■		

IPM Activities and Plant Monitoring Profile for California Tomatoes: NORTHERN SAN JOAQUIN VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Soil Sampling	■	■	■						■	■		
Insecticide App.				■	■	■	■	■	■	■		
Herbicide App.	■		■	■	■	■	■	■			■	
Fungicide App.			■	■	■	■	■	■	■	■		
Insect Scouting			■	■	■	■	■	■	■	■		
Disease Scouting			■	■	■	■	■	■	■	■		

Table 5 Cultural Activities Profile for California Tomatoes: SOUTHERN SAN JOAQUIN VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep		■	■	■	■	■	■					
Transplant		■	■	■	■	■	■					
Seed												
Fertilization			■	■	■	■	■	■				
Thinning												
Irrigation		■	■	■	■	■	■	■	■			
Cultivation			■	■	■	■	■	■				
Harvest						■	■	■	■	■	■	

IPM Activities and Plant Monitoring Profile for California Tomatoes: SOUTHERN SAN JOAQUIN VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Soil Sampling		■	■									
Insecticide App.			■	■	■	■	■	■	■	■		
Herbicide App.			■	■	■	■	■					
Fungicide App.							■	■	■	■		
Insect Scouting			■	■	■	■	■	■	■	■		
Disease Scouting		■	■	■	■	■	■	■	■	■		

Table 6 **Cultural Activities Profile for California Tomatoes: CENTRAL COAST**

	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep		■	■	■	■							
Transplant				■	■	■						
Seed												
Fertilization			■	■	■	■	■	■	■	■		
Thinning				■	■	■	■					
Irrigation			■	■	■	■	■	■	■	■		
Cultivation			■	■	■	■	■	■				
Harvest								■	■	■		

IPM Activities and Plant Monitoring Profile for California Tomatoes: CENTRAL COAST

	J	F	M	A	M	J	J	A	S	O	N	D
Soil Sampling		■	■	■								
Insecticide App.					■	■	■	■	■			
Herbicide App.				■	■	■	■					
Fungicide App.							■	■	■	■		
Insect Scouting				■	■	■	■	■	■	■		
Disease Scouting				■	■	■	■	■	■	■		

Table 7 **Cultural Activities Profile for California Tomatoes: SOUTH COAST**

	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep		■	■	■								
Transplant			■	■	■	■	■					
Seed												
Fertilization			■	■	■	■	■	■	■	■	■	
Thinning												
Irrigation			■	■	■	■	■	■	■	■	■	
Cultivation		■	■	■	■	■	■	■	■	■	■	■
Harvest					■	■	■	■	■	■	■	■

IPM Activities and Plant Monitoring Profile for California Tomatoes: SOUTH COAST

	J	F	M	A	M	J	J	A	S	O	N	D
Soil Sampling				■	■						■	■
Insecticide App.		■	■	■	■	■	■	■	■	■	■	■
Herbicide App.	■	■	■	■	■	■						
Fungicide App.			■	■	■	■	■	■	■	■	■	■
Insect Scouting		■	■	■	■	■	■	■	■	■	■	■
Disease Scouting			■	■	■	■	■	■	■	■	■	■

Table 8 Cultural Activities Profile for California Tomatoes: IMPERIAL VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Bed Prep	■	■	■							■	■	■
Transplant	■	■	■									
Seed	■	■										
Fertilization	■	■	■	■	■					■	■	■
Thinning	■	■										
Irrigation	■	■	■	■	■	■						
Cultivation	■	■	■	■	■							
Harvest					■	■						

IPM Activities and Plant Monitoring Profile for California Tomatoes: IMPERIAL VALLEY

	J	F	M	A	M	J	J	A	S	O	N	D
Soil Sampling	■	■							■	■	■	■
Insecticide App.	■	■	■	■	■	■						
Herbicide App.	■	■	■							■	■	■
Fungicide App.	■	■	■	■								
Insect Scouting	■	■	■	■	■	■						
Disease Scouting	■	■	■	■	■	■						

Table 9 **Seasonal Pest Occurrence in California Tomatoes: NORTHERN SAN JOAQUIN VALLEY**

INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Stink Bug												
Tomato Fruitworm												
Variegated Cutworm												
Cabbage Looper												
Tomato Pinworm												
Beet Armyworm												
Silverleaf Whitefly												
Hornworm												
Potato Aphid												
Green Peach Aphid												
Leafminer												
Spider Mite												
Russet Mite												
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight												
Powdery Mildew												
Phytophthora												
Black Mold												
Botrytis Grey Mold												
Bacterial Speck												
Bacterial Spot												
Tomato Spotted Wilt Virus												
Other Viruses												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nightshades												
Nutsedge												
Dodder												
Bindweed												
Annual grasses												
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot Nematode												
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Horned Larks												
Crows												
Gophers												

Table 10 **Seasonal Pest Occurrence in California Tomatoes: SOUTHERN SAN JOAQUIN VALLEY**

INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Stink Bug						■	■	■	■	■		
Tomato Fruitworm						■	■	■	■	■		
Variegated Cutworm			■	■	■	■	■					
Cabbage Looper					■	■	■	■	■	■		
Tomato Pinworm						■	■	■	■	■		
Beet Armyworm						■	■	■	■	■		
Silverleaf Whitefly												
Hornworm						■	■	■	■	■		
Potato Aphid					■	■	■	■	■	■		
Green Peach Aphid					■	■	■	■	■	■		
Leafminer							■	■	■	■		
Spider Mite							■	■	■	■		
Russet Mite							■	■	■	■		
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight									■	■		
Powdery Mildew							■	■	■	■		
Phytophthora							■	■	■	■		
Black Mold									■	■		
Botrytis Grey Mold									■	■		
Bacterial Speck			■	■	■	■			■	■		
Bacterial Spot												
Tomato Spotted Wilt Virus				■	■	■	■	■	■			
Other Viruses												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nightshades					■	■	■	■				
Nutsedge					■	■	■	■				
Dodder						■	■	■				
Bindweed						■	■	■				
Annual grasses						■	■	■	■	■		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot Nematode			■	■	■	■	■	■	■	■		
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Horned Larks												
Crows												
Gophers			■	■	■	■	■	■	■	■		

Table 11 **Seasonal Pest Occurrence in California Tomatoes: CENTRAL COAST**

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Stink Bug						■	■	■	■	■		
Tomato Fruitworm						■	■	■	■	■		
Variegated Cutworm			■	■	■	■	■					
Cabbage Looper					■	■	■	■	■	■		
Tomato Pinworm						■	■	■	■	■		
Beet Armyworm						■	■	■	■	■		
Silverleaf Whitefly												
Hornworm						■	■	■	■	■		
Potato Aphid					■	■	■	■	■	■		
Green Peach Aphid					■	■	■	■	■	■		
Leafminer							■	■	■	■		
Spider Mite							■	■	■	■		
Russet Mite							■	■	■	■		
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight									■	■		
Powdery Mildew							■	■	■	■		
Phytophthora							■	■	■	■		
Black Mold									■	■		
Botrytis Grey Mold									■	■		
Bacterial Speck			■	■	■	■			■	■		
Tomato Infectious Chlorosis Virus							■	■	■			
Tomato Spotted Wilt Virus				■	■	■	■	■	■			
Other Viruses												
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nightshades					■	■	■	■				
Nutsedge												
Dodder												
Bindweed						■	■	■				
Annual grasses						■	■	■	■	■		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot Nematode			■	■	■	■	■	■	■	■		
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Horned Larks												
Crows												
Gophers			■	■	■	■	■	■	■	■		

Table 12 **Seasonal Pest Occurrence in California Tomatoes: SOUTHERN COAST**

INSECTS/MITES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Stink Bug					X	X	X	X	X	X		
Tomato Fruitworm					X	X	X	X				
Variegated Cutworm			X	X	X	X						
Cabbage Looper					X	X	X	X	X	X		
Tomato Pinworm						X	X	X	X	X		
Beet Armyworm						X	X	X	X	X		
Silverleaf Whitefly				X	X	X	X	X	X	X	X	X
Hornworm												
Potato Aphid			X	X								
Green Peach Aphid					X	X	X	X	X	X		
Leafminer							X	X	X	X		
Spider Mite						X	X	X	X	X		
Russet Mite						X	X	X	X	X		
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight			X	X	X	X	X	X	X	X		
Powdery Mildew						X	X	X	X	X		
Phytophthora			X	X	X	X	X	X	X	X		
Black Mold												
Botrytis Grey Mold				X	X					X	X	X
Bacterial Speck			X	X	X						X	X
Tomato Infectious Chlorosis Virus							X	X	X			
Tomato Spotted Wilt Virus					X	X						
Other Viruses						X	X	X	X	X		
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nightshades				X	X	X						
Nutsedge				X	X	X	X					
Dodder												
Bindweed												
Annual grasses			X	X	X	X	X	X	X	X		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot Nematode			X	X	X	X	X	X	X	X		
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Horned Larks												
Crows						X	X	X	X	X	X	X
Gophers												

Table 13 **Seasonal Pest Occurrence in California Tomatoes: IMPERIAL VALLEY**

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Stink Bug												
Tomato Fruitworm		■	■	■	■	■						
Variegated Cutworm	■	■	■									
Cabbage Looper		■	■	■	■	■						
Tomato Pinworm				■	■	■						
Beet Armyworm		■	■	■	■	■						
Silverleaf Whitefly		■	■	■	■	■	■	■	■	■	■	■
Hornworm		■	■	■	■	■						
Potato Aphid	■	■	■	■	■							
Green Peach Aphid	■	■	■									
Leafminer			■	■	■	■						
Spider Mite	■	■	■	■	■	■						
Russet Mite			■	■	■	■						
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight	■	■	■	■								
Powdery Mildew		■	■	■	■							
Phytophthora	■	■	■	■	■							
Black Mold		■	■	■								
Botrytis Grey Mold		■	■	■								
Bacterial Speck		■	■	■								
Bacterial Spot		■	■	■								
Tomato Spotted Wilt Virus		■	■	■	■							
Other Viruses	■	■	■	■	■							
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Nightshades	■	■	■									
Nutsedge	■	■	■	■	■	■						
Dodder			■	■	■							
Bindweed	■	■	■	■	■	■						
Annual grasses			■	■	■	■						
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Root Knot Nematode	■	■	■	■	■	■						
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Horned Larks	■	■										
Crows	■	■										
Gophers	■	■	■	■	■	■	■	■	■	■	■	■
Coyotes	■	■	■	■	■	■	■	■	■	■	■	■

Table 14

Efficacy of Insect Management Tools Used in California Fresh Market Tomatoes																			
Product	**Trade Name**	Stink Bug	Tomato Fruitworm	Variegated Cutworm	Cabbage Looper	Tomato pinworm	Beet Armyworm	West. Yellow Stripe Armyworm	Silverleaf Whitefly	Hornworm	Potato Aphid	Green Peach Aphid	Leafminer	Spider Mite	Russet Mite	thrips	Psyllids	Greenhouse Whitefly	
Abamectin	Agri-Mek												E	E					
Azadirachtin	Neemix													F		F			
Bacillus thuringiensis	Bt		F		G		F/G	G		E									
Carbaryl	Sevin			G						G									
Cyromazine	Trigard												E						
Diazinon	Diazinon			G															
Dicofol	Kelthane													G	E				
Dimethoate	Dimethoate										G	G							
Endosulfan	Thiodan	G									G	G							
Esfenvalerate	Asana XL	F	G		G		F		F							F		F	
Imidacloprid	Admire								E		G	G	F			E			
Methamidophos	Monitor	G/E			G		F				G	G							
Methomyl	Lannate		G		G	G	G	G	F		G	G						F	
Oxamyl	Vydate								F		G	G						F	
Permethrin	Pounce	F	F		G	R	F	F		G	F	F				F			
Potash Soap	M-Pede	P																	
Spinosad	Success		G		E		F/G	P		G			F/G			G			
Sulfur	Sulfur													F	E				
Indoxacarb	Avaunt		F		G		F	F		G									
Tebufenozide	Confirm		F		G		G	G											
Pymetrozine	Fulfill																		

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
E = Excellent G = Good F=Fair P=Poor/None R=Known Resistance

Table 15

Efficacy of Non-Chemical Insect Management Tools Used in California Fresh Market Tomatoes

Non-chemical Tools	Stink Bug	Tomato Fruitworm	Variegated Cutworm	Cabbage Looper	Tomato pinworm	Beet Armyworm	West. Yel. Armyworm	Silverleaf Whitefly	Hornworm	Potato Aphid	Green Peach Aphid	Leafminer	Spider Mite	Russet Mite	Thrips	Psyllid	Greenhouse Whitefly
Cover Crops	P																
Habitat management	F																
Monitoring/use of action thresholds	E	E	E	E	E	E	E	E	E	E	E	E	E	F	G	E	E
Natural enemies	P	G		G	P/F	P			E	P	P	G	F		P	P	
Nutrition																	
Sanitation	F														F		
Soil/dust management			F														
Use of models																	
Resistant varieties										F	F						
Water management																	
Weed control	F														F		F
Mulching										F	F						
Trap Crops																	
Netting	E	E		E	E	E	G	G	E	E	E	G					
Mating Disruption					E												
Pheromone (monitor)	F	G			E	E											

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

<u>Rating System</u>
E = Excellent G = Good F=Fair P=Poor/None R=Known Resistance

Table 16

Relative Toxicity of Insecticides to Beneficial Organisms in California Fresh Market Tomatoes									
Product	**Trade Name**	Big-eyed Bugs	Damsel Bugs	Green Lacewings	Lady Bird Beetles	Minute Pirate Bugs	Parasites	Spiders	Syrphid Fly Larvae
Abamectin	Agri-Mek	S	S	S	O	S	O	U	S
Azadirachtin	Trilogy	U	U	M	M	U	M	U	U
Bacillus thuringiensis	Bt	O	O	O	O	O	O	O	O
Carbaryl	Sevin	H	H	H	H	H	H	H	H
Cyromazine	Trigard	O	O	O	O	O	O	O	U
Diazinon	Diazinon	H	H	H	H	H	H	H	H
Dicofol	Kelthane	O	O	O	O	O	O	U	O
Dimethoate	Dimethoate	H	H	H	H	H	H	H	H
Endosulfan	Thiodan	H	H	U	U	H	S	U	U
Esfenvalerate	Asana XL	H	H	H	H	H	H	H	H
Imidacloprid	Admire	O	O	O	O	O	O	O	O
Methamidophos	Monitor	H	H	H	H	H	H	H	H
Methomyl	Lannate	H	H	H	H	H	H	H	H
Oxamyl	Vydate	M	M	M	M	M	M	U	M
Permethrin	Pounce	H	H	H	H	H	H	H	H
Potash Soap	M-Pede	O	O	O	O	O	O	O	O
Spinosad	Success	S	S	S	S	S	S	S	S
Sulfur	Sulfur	O	O	O	O	O	O	U	O
Indoxacarb	Avaunt	U	U	U	U	U	S	U	U
Tebufenozide	Confirm	O	O	O	O	O	O	O	O
Pymetrozine	Fulfill	O	O	O	O	O	O	O	O

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
U= Unknown O= No Effect S= Soft M= Moderate H= Harsh

Table 17

Efficacy of Disease Management Tools Used in California Fresh Market Tomatoes

Product	**Trade Name**	Late Blight	Powdery Mildew	Phytophthora	Black Mold	Botrytis Grey Mold	Bacterial Speck	Bacterial Spot	Other Viruses
Azoxystrobin	Quadris	F	F/P						
Chlorothalonil	Bravo	G				G			
Copper Hydroxide	Copper Hydroxide	P					F	F	
Mancozeb	Dithane	F/G							
Mefenoxam	Ridomil Gold			F/G					
Sulfur	Sulfur		F/P						
Non-chemical Tools									
Models (i.e. disease forecasting)		G	F						
Irrigation management		E	G	E			E	E	
Weed control									
Resistant varieties							E		
Cover crops									
Adjusted planting date		F					F	F	
Adjusted harvest date		F							
Fertilizer management									
Vector control									P
Biological control									

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
E = Excellent G = Good F=Fair P=Poor/None R=Known Resistance

Table 18

Efficacy of Nematode Management Tools Used in California Tomatoes

Product	Trade Name	Root Knot Nematode
Metam-Sodium	Vapam	G
Non-chemical Tools		
Fallow		P
Monitoring-soil samples		G
Cover crops		F
Soil/water management		P
Resistant varieties		F
Soil Solarization		G
Fertilizer management		P

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
E = Excellent G = Good F=Fair P=Poor/None R=Known Resistance

Table 19

Efficacy of Weed Management Tools Used in California Fresh Market Tomatoes														
Product	**Trade Name**	**Timing***	Nightshades	Nutsedge	Barnyardgrass	Bindweed	Pigweeds	Johnsongrass	Bermudagrass	Volunteer cereals	Lambsquarters	Crabgrass	Velvetleaf	Purslane
EPTC	Eptam	LB	G	G	E	P	E	F	P	E	F	E	P	E
Glyphosate	Roundup	PPF	E	F	E	F	E	F	F	E	E	E	E	E
Halosulfuron	Sandea	LB		G										
Metolachlor	Dual Magnum	PP, PPI		G										
Metam-Sodium	Vapam	PPF	G	F	E	F	E	F	G	E	E	E	E	E
Metribuzin	Sencor	PP,POE	F	N	F	P	E	P	P	F	E	E	G	F
Napropamide	Devrinol	PPI	P	P	E	P	E	P	F	E	E	E	P	E
Oxyfluorfen	Goal	PP	E	P	F	P	E	P	P	P	E	F	E	E
Paraquat Dichloride	Gramoxone	PPF	E	P	E	P	E	P	P	E	F	E	F	E
Pebulate	Tillam	PPI, LB	F	F	E	P	E	P	P	E	E	E	P	G
Sethoxydim	Poast	POE	P	P	E	P	P	E	E	E	P	E	P	P
Trifluralin	Treflan	PPI,LB	P	P	E	P	E	P	P	P	E	E	P	E
Non-chemical Tools														
Cultivation			G	P	F	F	G	P	F	G	G	G	F	G
Soil/Water management			F	P	P	P	F	P	P	P	P	F	P	F
Cover crops			P	P	P	P	P	P	P	P	P	P	P	P
Crop Rotation			G	G	G	G	G	F	F	F	F	F	G	G
Pre-irrigation			F	P	F	P	F	P	P	G	G	G	F	G
Subsurface drip irrigation			E	P	F	P	E	P	P	F	E	E	F	E
Hand weeding			E	P	F	F	E	P	P	G	E	G	G	G
Use of transplants			F	P	F	P	F	P	P	F	F	F	P	F
Adjusted planting date			F	F	F	F	F	F	F	P	P	P	F	F
Resistant Varieties			P	P	P	P	P	P	P	P	P	P	P	P

Data based on collective field observations and experiments by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
E = Excellent G = Good F=Fair P=Poor N=No Control R=Known Resistance

* Timing
LB= Layby PPF= Postplant foliar PP= Preplant PPI= Preplant Incorporated
POE= Postemergence

Table 20

Efficacy of Rodent & Other Vertebrate Controls in California Fresh Market Tomatoes					
Technique	Crows	Voles	Gophers	Squirrels	Coyotes-Foxes
Prevention	N	F	N	N	N
Exclusion	N	F	N	N	N
Predators	N	F	P	N	N
Cultural Barriers	N	F	N	N	N
Trapping	N	G	F	N	F
Bait Stations	N	F	F	F-G	N
Lethal Control	needed	P	F	G	needed
Noise	F	N	N	N	N
Repellent	N	N	N	N	N
Mylar Strips	N	N	N	N	N

Data based on collective field observations by growers, Pest Control Advisers, and University of California Cooperative Extension Farm Advisers.

Rating System
E = Excellent G = Good F=Fair P=Poor N=No Control R=Known Resistance

Table 21

Total Pounds of Insecticide and Miticide Used in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Avermectin	Agri-Mek	12	33	36	41	31
Azadirachtin	Trilogy	178	184	212	322	224
Azinphos-Methyl	Guthion	909	875	166	223	543
Bacillus thuringiensis	Bt	335	161	4,299	4,986	2,445
Carbaryl	Sevin	3,254	4,127	4,105	3,185	3,668
Cyromazine	Trigard	52	15	88	25	45
Diazinon	Diazinon	1,301	729	842	1,577	1,112
Dicofol	Kelthane	470	261	347	1,356	609
Dimethoate	Dimethoate	6,622	9,410	5,604	2,942	6,145
Endosulfan	Thiodan	1,008	2,087	2,226	936	1,564
Esfenvalerate	Asana XL	1,119	953	1,165	862	1,025
Imidacloprid	Admire	1,568	1,807	1,652	1,719	1,687
Methamidophos	Monitor	15,265	9,570	4,034	5,308	8,544
Methomyl	Lannate	29,142	30,557	20,932	11,209	22,960
Oxamyl	Vydate	2,559	4,121	2,089	6,281	3,763
Permethrin	Pounce	1,923	1,497	825	475	1,180
Potash Soap	M-Pede	497	2,452	40,158	2,479	11,397
Spinosad	Success	828	1,124	1,384	1,302	1,160
Tebufenozide	Confirm	0	0	4,251	2,913	1,791

Table 22

% Acres Treated With Insecticides in California Fresh Market Tomatoes (1998-2000)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Avermectin (abamectin)	Agri-Mek	2	8	8	5	6
Azadirachtin	Trilogy	5	5	4	6	5
Azinphos-Methyl	Guthion	1	1	0	1	1
Bacillus thuringiensis	Bt	42	36	37	34	37
Carbaryl	Sevin	8	10	9	11	10
Cyromazine	Trigard	1	0	1	0.4	0.6
Diazinon	Diazinon	3	2	1	2	2
Dicofol	Kelthane	1	1	1	3	1.5
Dimethoate	Dimethoate	22	27	18	10	19
Endosulfan	Thiodan	1	4	3	2	3
Esfenvalerate	Asana XL	34	29	33	28	31
Imidacloprid	Admire	13	18	16	19	17
Methamidophos	Monitor	24	17	8	14	16
Methomyl	Lannate	46	42	36	22	37
Oxamyl	Vydate	3	7	4	8	6
Permethrin	Pounce	13	9	6	6	9
Potash Soap	M-Pede	0	1	14	1	4
Spinosad	Success	9	15	16	18	15
Tebufenozide	Confirm	0	0	63	27	23

Table 23

Total Pounds Herbicide Used in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
EPTC	Eptam	848	198	816	24	472
Glyphosate	Roundup	7,617	8,429	12,960	6,439	8, 936
Metam-Sodium	Vapam	68,914	123,551	140,846	157,708	122,755
Metribuzin	Sencor	1,626	2,040	1,600	1,267	1,633
Napropamide	Devrinol	746	1,000	589	770	776
Oxyfluorfen	Goal	1,789	1,130	1,487	150	1,139
Paraquat Dichloride	Gramoxone	2,392	514	1,257	480	1,161
Pebulate	Tillam	7,190	8,365	7,933	2,499	6,497
Sethoxydim	Poast	476	259	205	282	306
Trifluralin	Treflan	7,739	10,981	9,711	6,410	8,710

Table 24

% Acres Treated With Herbicides in California Fresh Market Tomatoes (1998-2000)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
EPTC	Eptam	1	0	1	0	0.5
Glyphosate	Roundup	15	13	24	12	16
Metam-Sodium	Vapam	2	4	6	6	5
Metribuzin	Sencor	6	8	8	7	7
Napropamide	Devrinol	1	3	1	1	2
Oxyfluorfen	Goal	12	9	9	3	8
Paraquat Dichloride	Gramoxone	4	2	3	1	3
Pebulate	Tillam	3	4	5	2	4
Sethoxydim	Poast	3	2	2	1	2
Trifluralin	Treflan	21	30	30	26	27

Table 25

Total Pounds Fungicide Used in California Fresh Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Azoxystrobin	Quadris	2,157	2,326	2,072	1,703	2,065
Chlorothalonil	Bravo	99,429	61,714	58,426	62,238	70,452
Copper Hydroxide	Copper Hydroxide	87,361	21,201	28,735	13,254	37,638
Mancozeb	Dithane	46,296	24,487	27,500	20,442	29,681
Mefenoxam	Metalaxyl-M	846	1,061	1,027	1,010	986
Metalaxyl	Ridomil	759	78	24	46	227
Propamocarb	Tattoo C	6,431	3,012	3,263	2,018	3,681
Myclobutanil	Rally	225	4	25	679	233
Sulfur	Sulfur	687,274	514,753	527,227	271,797	500,263

Table 26

% Acres Treated With Fungicides in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Azoxystrobin	Quadris	31	30	27	23	28
Chlorothalonil	Bravo	48	31	37	33	37
Copper Hydroxide	Copper Hydroxide	40	16	22	14	23
Mancozeb	Dithane	37	24	26	24	28
Mefenoxam	Metalaxyl-M	26	26	25	28	26
Metalaxyl	Ridomil	6	1	0	1	2
Myclobutanil	Rally	6	0	1	9	4
Propamocarb	Tattoo C	23	11	11	4	12
Sulfur	Sulfur	41	39	36	29	36

Table 27

Total Pounds nematicides Used in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Chloropicrin	Chloropicrin	92,089	140,911	109,082	139,679	120,440
Metam-sodium	Vapam	68,914	123,551	140,846	157,708	122,755
Methyl bromide	Methyl bromide	301,372	381,187	205,623	123,894	253,019

Table 28

% Acres Treated With Nematicides in California Fresh Market Tomatoes (1998-2000)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Chloropicrin	Chloropicrin	5	6	5	4	5
Metam-sodium	Vapam	2	4	6	6	5
Methyl Bromide	Methyl Bromide	5	7	5	3	5

Table 29

Total Pounds Plant Growth Regulator Used in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Ethephon	Ethrel	3,389	2,469	2,201	1,296	1,844

Table 30

% Acres Treated with Plant Growth Regulators in California Fresh Market Tomatoes (1998-2001)

Product	Trade Name	1998	1999	2000	2001	4 Year Average
Ethephon	Ethrel	6	5	4	4	5

Members of the California Fresh Market Tomato Work Group in Attendance

Growers, Packers, and Shippers

1. Jeff Dolan, DiMare Company, Newman, CA
2. Charlie Duncan, San Joaquin Tomato Growers, Crows Landing, CA
3. Mike Marchini, Live Oak Farms, Le Grand, CA
4. Tom Perez, San Joaquin Tomato Growers, Crows Landing, CA
5. Ronald Oneto, KLM Ranches, Elk Grove, CA
6. Jeff Rurup, Ace Tomato, Stockton, CA
7. Mark Covello, West Coast Tomato, Stockton, CA
8. Mike Navarro, Bianchi & Sons, Merced, CA

Commodity Group Representatives

9. Lori Berger, Director of Technical Affairs, CA Minor Crops Council, Visalia, CA
10. John LeBoeuf, CTC Research Coordinator, Fresno, CA

Pest Control Advisers

11. James Colyn, Stockton, CA
12. Mark Hoatson, LeGrande, CA
13. Jim Hudgins, Oceanside, CA
14. Jimmie Ledford, Firebaugh, CA
15. Steve Thorpe, Newman, CA

Land Grant University Research and Extension Personnel

16. Mike Davis, Plant Pathology Research, UC Davis
17. Benny Fouche, Farm Advisor and Entomology Research, UCCE San Joaquin County
18. Bob Gilbertson, Plant Pathology Research, UC Davis
19. Tim Hartz, Vegetable Crops Research, UC Davis
20. Michelle LeStrange, Farm Advisor Vegetable Crops, UCCE Tulare/Kings Counties
21. Bob Mullen, Farm Advisor and Plant Pathology Research, UCCE San Joaquin County
22. Scott Stoddard, Research Associate, UCCE Merced County
23. John Trumble, Entomology Research, UC Riverside
24. Jesus Valencia, Farm Advisor Vegetable Crops, UCCE Fresno County

US-EPA

25. Ann Thrupp, EPA Region 9 Agricultural Initiative, San Francisco, CA

California Pest Management Center

26. Linda Herbst, Asst. Director, Western Region Pest Management Center, U.C. Davis
27. Rick Melnicoe, Director of Western Region Pest Management Center, U.C. Davis

Other Invited Guests not in Attendance

28. Pat Cimino, USEPA Minor Crops Advisor, Washington, D.C.
29. Kathy Davis or B.E.A.D. Representative, US-EPA, Washington, DC
30. Gail Tomimatsu, Pesticide Environmental Stewardship Program, Washington, D.C.
31. Wilfred Burr, USDA - ARS-Office of Pest Management Policy, Washington, D.C.
32. Becky Sisco, IR-4, U.C. Davis

California Tomato Commission – Additional Review Team

1. Ed Beckman, President
2. Mike Gardoni, Gonzales Packing, Pest Management sub-committee
3. Bob Giampaoli, Live Oak Farms, Pest Management sub-committee
4. Tom Guido, Triple E/Pacific Tomato Growers, Pest Management sub-committee
5. Andrew Murphy, O.P. Murphy & Sons, Pest Management sub-committee
6. John Teixeira, Teixeira & Sons, Pest Management sub-committee

California Fresh Market Tomato Industry - Contact Information

1. Ed Beckman, President, California Tomato Commission
   1625 East Shaw Avenue, Suite 106, Fresno, Ca 93710
   Ph: (559)230-0635 Fax: (559) 230-0635 Email: Beckman@tomato.org

2. Lori Berger, Director of Technical Affairs, California Minor Crops Council
   4437 S. Laspina, Suite 214, Tulare, CA 93274
   Ph: (559) 799-8266 Email: lori@minorcrops.org

3. Jim Colyn, Pest Control Adviser, Mid Valley Ag
   P.O. Box 593, Linden, CA 95236
   Ph: (209) 931-9411 Fax: (209) 931-0747 Area covered: SJV

4. Mark Covello, Field Supervisor, West Coast Tomato
   2900 E. Harding Way, Stockton, CA 95207
   Ph: (209) 464-4534 Area covered: SJV

5. Dr. Mike Davis, Cooperative Extension Specialist, UC Davis – Dept. of Plant Pathology
   One Shields Ave., University of California, Davis, CA 95616
   Ph: (530) 752-0303 Fax: (530) 752-1199 Email: rmdavis@ucdavis.edu
   Areas covered: State

6. Jeff Dolan, Field Manager/Grower, The DiMare Co./Agricola Land Co.
   P.O. Box 517, Newman, CA 95360
   Ph: (209) 862-2872 Fax: (209) 862-0103
   Email: JDolan@DiMare-CA.com Areas covered: SJV, Desert

7. Charles Duncan, Field Supervisor, San Joaquin Tomato
   P.O. Box 578, Crows Landing, CA 95313
   Ph: (209) 837-4721 Fax: (209) 837-4242 Area covered: SJV

8. Calvin "Benny" Fouche, Farm Advisor, UCCE San Joaquin County
   420 South Wilson Way, Stockton, CA 95205
   Ph: (209) 468-9491 Area covered: SJV

9. Dr. Bob Gilbertson, Professor, UC Davis - Dept of Plant Pathology
   One Shields Ave., University of California, Davis, CA 95616
   Ph: (530) 752-3163 Fax: (530) 752-5674 Email: rlgilbertson@ucdavis.edu

10. Tim Hartz, Extension Specialist, UC Davis - Dept. of Vegetable Crops
    One Shields Ave., University of California, Davis, CA 95616
    Ph: (530) 752-1738 Fax: (530) 752-9659 Email: hartz@vegmail.ucdavis.edu

11. Linda Herbst, Assistant Director, Western Region Pest Management Center
    One Shields Ave., University of California, Davis, CA 95616
    Ph: (530) 752-7010 Fax: (530) 754-8379 Email: llherbst@ucdavis.edu

12. Mike Hoatson, Pest Control Adviser, Simplot Grower Solutions
    10985 Ballico Avenue, Ballico, CA 95330
    Ph: (209) 761-3499 Fax: (209) 389-0261 Area covered: SJV

13. Jim Hudgins, Pest Control Adviser, Oceanside Produce
    P.O. Box 1850, Oceanside, CA 92051
    Ph: (760) 758-9299 Fax: (760) 758-4687 Area covered: South Coast

14. John LeBoeuf, Research Coordinator, AgriDataSensing, Inc.
    8398 N. 9th St., Fresno, CA 93270
    Ph: (559) 431-2360 Fax: (559) 431-2360 Email: jbleboeuf@aol.com

15. Jimmie Ledford, Pest Control Adviser, Teixeira & Sons Farms
    1150 Pointe Vale, Gustine, CA 95322
    Ph: (209) 704-6639 Fax: (209) 238-0174 Email: tomato@inreach.com
    Area covered: SJV

16. Michelle LeStrange, Farm Advisor – UCCE Tulare County
    4437 S. Laspina St., Suite B, Tulare, CA 93274
    Ph: (559) 685-3309 ext.220 Fax: (559) 685-3319
    Email: mlestrange@ucdavis.edu Area covered: SJV

17. Mike Marchini, Grower, Live Oak Farms
    P.O. Box 65, LeGrand, CA 95333
    Ph: (209) 389-4576 Area covered: SJV

18. Dr. Milt McGiffen, Extension Vegetable Spec., Dept. of Botany
    University of California, Riverside, CA 92521-0124
    Ph: (909) 560-0839 Fax: (909) 787-5717 Email: milt@citrus.ucr.edu

19. Rick Melnicoe, Director, Western Region Pest Management Center
    One Shields Ave., University of California, Davis, CA 95616
    Ph: (530) 754-8378 Fax: (530) 754-8379 Email: rsmelnicoe@ucdavis.edu

20. Bob Mullen, Farm Advisor, UCCE San Joaquin County
    420 South Wilson Way, Stockton, CA 95205
    Ph: (209) 468-9489 Fax: (209) 462-5181 Email:rjmullen@ucdavis.edu
    Area covered: SJV

21. Mike Navarro, Farm Manager, Bianchi & Sons
    P.O. Box 190, Merced, CA 95341
    Ph: (209) 722-8134 Fax: (209) 722-4013 Area covered: SJV

22. Ron Oneto, Grower, KLM Ranches Inc.
    7407 Grenfell Ct., Elk Grove, CA 95758
    Ph: (916) 505-9208 Fax: (916) 684-2900 Email: Roneto@aol.com
    Areas covered: Sacramento Valley, NSJV

23. Tom Perez, President, San Joaquin Tomato
    P.O. Box 578, Crows Landing, CA 95313
    Ph: (209) 837-4721 Fax: (209) 837-4242 Area covered: SJV

24. Dr. Antoon Ploeg, Extension Specialist, Department of Nematology
    University of California, Riverside, CA 92521
    Ph: (909) 787-3192 Fax: (909) 787-3719 Email: antoon.ploeg@ucr.edu

25. Chuck Rivara, Director, California Tomato Research Institute, Inc.
    18650 E. LoneTree Rd., Escalon, CA 95320
    Ph: (209) 838-1594 Fax: (209) 838-1595 Email: chuck@tomatonet.org
    Areas covered: Processing Tomatoes in Sac, SJV

26. Jeff Rurup, Field Manager, Ace Tomato Co. Inc.
    2217 E. French Camp Rd., Manteca, CA 95336-9224
    Ph: (209) 982-5691 Fax: (209) 982-0235 Area(s) covered: SJV

27. Rebecca Sisco, Regional Field Coordinator, Western Region IR-4 Program
    University of California, Dept. Environmental Toxicology
    One Shields Ave., 4218 Meyer Hall, Davis, CA 95616
    Ph: (530) 752-7634 Fax: (530) 752-2866 Email: rsisco@ucdavis.edu

28. Scott Stoddard, Farm Adviser, UCCE Merced County
2145 Wardrobe Ave., Merced, CA 95340
Ph: (209) 385-7403 Fax: (209) 722-8856 Email: csstoddard@ucdavis.edu
Area covered: SJV

29. Steve Thorpe, Pest Control Adviser, DiMare Company
3779 Duck Blink Dr., Newman, CA 95363
Ph: (209) 602-2318 Fax: (209) 862-3779 Area covered: SJV

30. Dr. Ann Thrupp, Life Scientist, Agriculture Initative EPA Region 9
EPA Region 9-CMD-41, 75 Hawthorne St., San Francisco, CA 94105
Ph: (415) 947-4242 Email: thrupp.loriann@epa.gov

31. Dr. John Trumble, Entomologist, Dept. of Entomology
University of California, Riverside, CA 92521
Ph: (909) 787-5624 Fax: (909) 787-5624 Email: john.trumble@ucr.edu
Areas covered: SJV, Desert, South Coast

32. Jesus Valencia, Farm Advisor, UCCE-Fresno County
1720 So. Maple Ave., Fresno, CA 93722
Ph: (559) 456-7553 Email: jvalencia@ucdavis.edu Area covered: SJV