# Pest Management Strategic Plan

# For

# California Processing Tomato Production


**Prepared by:**

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# Executive Summary

Nearly all of the processed tomato products consumed in and exported from the United States (including tomato paste, ketchup, whole-peel canned tomatoes, tomato sauce, salsa, and more) are grown and produced in California. California-grown processing tomato accounts for nearly one-third of the global processed tomato market. Despite the significance of this crop to the national and global market for processed tomato products, the pest management priorities of the California processing tomato industry have never been formally documented. This has made it more difficult to address the major pest problems facing the industry and maintain its long-term sustainability.

This Pest Management Strategic Plan details the critical needs and priorities of the California processing tomato industry. It includes background information about processing tomato production in California and common cultural practices. Much of the Pest Management Strategic Plan focuses on the major pests and methods currently available to manage them, timing of various management practices, and efficacy of current management practices. The information in this document is based on stakeholder feedback and other supporting information (such as published research and extension resources). All participating stakeholders and their affiliations are listed at the end of this document. Stakeholders include growers, pest control advisers, processors, regulators, and Cooperative Extension professionals.

The California processing tomato industry is spread across four primary growing areas (see Background and Overview, Production Regions for more information). Though some pest issues are a concern throughout the state, pest pressure and priorities also differ substantially between northern growing regions (Areas I and II) and southern growing regions (Areas III and IV). We held two stakeholder meetings to capture regional and statewide needs—one on March 26, 2019 to address the needs of the northern region, and one on June 6, 2019 to address the needs of the southern region. The critical needs listed in this document are therefore separated into Statewide Critical Needs (summarizing critical needs that were common between the northern and southern regions), Northern Region Critical Needs, and Southern Region Critical Needs. Regional differences in pest problems and management approaches are also detailed in the Foundation for a Pest Management Strategic Plan where applicable.

# California Processing Tomato Production Overview and Background

PROCESSING TOMATO FACTS

- California processing tomatoes are worth approximately $1 billion per year. They comprise 90 to 95% of the processed tomato products consumed in the United States and over 30% of the world market.
- Processed tomatoes are one of the top 10 export products in the state and account for between 94 to 96% of the nation's processed tomato exports.
- In 2019, total yield of processing tomatoes in California was 11,186,000 tons, harvested from 228,000 acres of land. Yield ranged from 40.7 tons per acre in Sutter County to 54.1 tons per acre in Kings County.
- Production of organic processing tomatoes has been increasing steadily over the past several years, though it still accounts for less than 3% of California production (over 404,000 tons in 2019).
- Approximately 70% of California-grown processed tomatoes are consumed domestically, and around 30% of the crop is exported to other nations. Most of the exports go to the European Union, Canada, and China. Others include Japan, Mexico, Korea, and Turkey.
- As of 2017 and 2018 (respectively), the cost of producing one ton of processing tomatoes was $75 in the Sacramento Valley and northern Delta ($3,313 per acre) and $77 in the San Joaquin Valley ($4,461 per acre).

## Production Regions

Processing tomatoes are grown in four primary areas of California. These areas are described here and are also shown in Figure 1. While many of these areas have similar pressure from certain pests, each area also faces region-specific pest problems. Throughout this document, areas I and II are considered the northern growing region, and areas III and IV are considered the southern growing region.

### Area I: Sacramento Valley (Colusa, Sutter, Yolo, Solano and Sacramento counties)

The Sacramento Valley produces about one-quarter of California's processing tomatoes each year, including approximately 30% of the state's organic processing tomatoes. In 2019, Yolo County alone ranked second in the state for total yield (1,516,000 tons) and total organic yield (83,893 tons). Yolo County also has the second most processing tomato acreage in the state.

The Sacramento Valley experiences moderately hot summers, with average daily high temperatures of 92°F from June through September over the last five years (averaged from June through September, average highs vary slightly by county as well). It also receives moderate annual rainfall (20–23 inches of rain per year). Planting in this area typically occurs from late March to late May. Harvest occurs as early as July to as late as October.

**Area II: Northern San Joaquin Valley (San Joaquin, Stanislaus and Merced counties)**

This area accounts for 19 to 21% of the state's total processing tomato yield (2,092,000 tons in 2019), including 8% of the state's organic yield (33,574 tons in 2019). The average daily high from June to September is 92.1°F, and average annual rainfall over the last five years is 14 inches. Planting in Area II mostly occurs from late March to the end of May, and harvest typically occurs from late July to the end of October.

**Area III: Fresno and Kings counties**

This region produces the largest proportion of California processing tomatoes, accounting for 47% of the state's total production and over half of the state's organic production. Fresno County alone produced over 3.8 million tons of processing tomatoes (over one-third of the state's total yield) in 2019. Both counties in this area also regularly produce over 50 tons of processing tomato per acre (and nearly 60 tons per acre for Kings County in 2018). This area has relatively hot (91°F average high temperature from June to September) and dry conditions (average of 13.7 inches rainfall per year for the last five years). The planting period in this region is usually from early March to late May; in some locations, planting may occur in late February. The harvest period is typically from early July to early October but sometimes extends into mid-October.

**Area IV: Kern County**

Kern County usually produces between 4 and 5% of the state's total processing tomatoes each year, though it accounted for 2% of the state yield in 2019. In 2019, this county also produced about 7% of the state's organic processing tomatoes. Kern County experiences hot summers and receives little rainfall, with an average high temperature of 93°F from June to September, and an average of 9 inches of rain per year from 2015 through 2019. Planting in this area typically begins in the last week of February or first week of March and continues until the mid-April. Harvest typically begins in early July and may continue until mid-August or even through September, depending on yield. The amount of processing tomato acreage in Kern County has fallen steadily over time—while 740,000 acres in this county were planted with processing tomato in 2014, only 287,000 acres were planted with processing tomato in 2019.

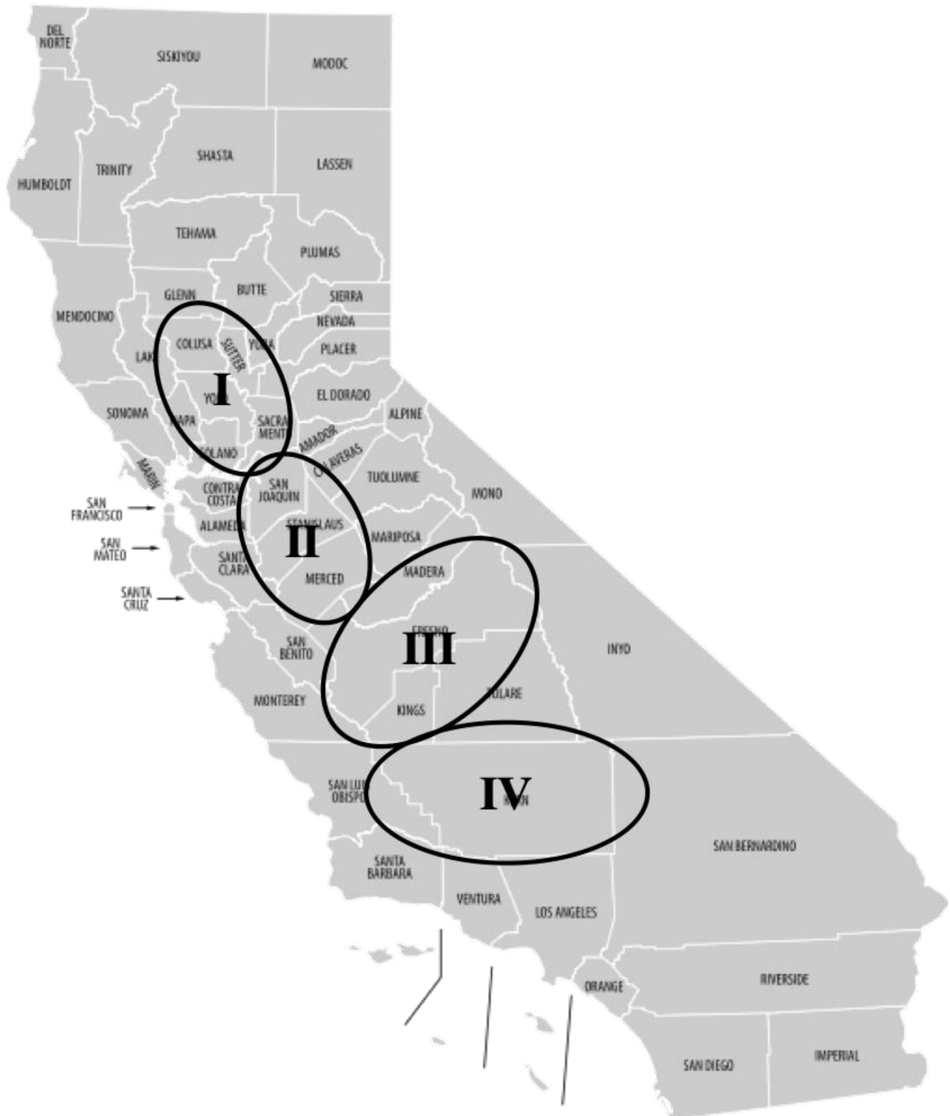


**Figure 1.** The major processing tomato growing regions of California.

## Processing Tomato Phenology

Three main maturity classifications of processing tomato varieties are grown in California: early maturity, mid maturity, and late maturity. Early-maturity varieties are usually planted earlier in the spring and harvested about 100 to 110 days after transplanting. Early-maturity varieties tend to be planted earlier in the season and have earlier harvest dates; however, they also tend to have lower yields. Mid-maturity varieties are harvested about 120 days after transplanting. Late-maturity varieties are harvested anywhere between 120 and 135 days after transplanting.

The timing of processing tomato development and phenology (e.g., time from planting to bloom, time from fruit set to first red fruit) can vary widely depending on various factors, including transplant age at planting, maturity classification, the specific variety planted, and particularly environmental factors. Though phenology models for specific stages of growth and development of California processing tomato have been attempted in the past, none have been able to broadly capture critical growth stages sufficiently. The first open flower of the crop usually appears within four weeks after transplanting, depending on environmental conditions and the age of the transplants at planting. Time to peak flowering is more variable; a single processing tomato plant can effectively flower (to be captured as ripe fruit at harvest) for as long as 4 to 5 weeks. The time between flowering and the first red fruit stage is typically between 40 and 60 days, and around 30 days pass between first red fruit and harvest (though this may be more than 40 days for late-maturity varieties).

Processing tomato is largely considered to be self-pollinated and wind-pollinated. Honey bee colonies are neither necessary nor effective for pollinaton and production of processing tomato; therefore, they are not placed in fields at any time during the growing season. However, visitation by native, nonmanaged bees has been found to increase fruit set and fruit size in field-grown tomatoes in Yolo and Sacramento counties. The bees that are capable of providing such benefits are those that engage in buzz pollination, in which the bee vibrates the flower to release the pollen from the stamens. Bees that engage in this behavior include bumble bees (*Bombus* spp.) and mud bees (*Anthophora* spp.). The benefits of native bee visitation in tomato has primarily been quantified for organic field-grown fresh market tomato; however, it is possible that processing tomato may also benefit from native buzz pollinators.

All processing tomatoes grown in California are determinate, with a bushy form at maturity and relatively concentrated fruit ripening. This enables fruit to be destructively harvested one time.

## Stakeholder Groups

Various organizations advocate and serve the processing tomato industry in California. The California Tomato Growers Association conducts marketing activities, promotes communication and bargaining between growers and processors, and advocates for fair prices and grading of the crop. The California Tomato Research Institute identifies, funds and directs research to maintain and increase processing tomato production, quality, and economic viability as well as reduce the environmental impacts of growing processing tomatoes. The Processing Tomato Advisory Board inspects and grades the harvested tomato fruit at the inspection locations, tracks the varieties used each year, records annual fruit tonnage (including that of organic production), and provides other resources to growers and California-based processing companies.

In addition to organizations that are specific to processing tomato, the California Association of Pest Control Advisers (CAPCA) represents and supports pest control advisers that serve the processing tomato industry, via education, legislative and regulatory representation, and communication with stakeholder groups. The California League of Food Producers represents stakeholders involved in both small and large food processing operations via advocacy with various branches of the state government, including both elected officials and regulatory agencies.

# Critical Needs of The California Processing Tomato Industry

The following critical needs are the top priorities of the processing tomato industry in California. Needs are grouped as follows:

1) Statewide Critical Needs: priorities mentioned by stakeholders in both the northern and southern processing tomato growing regions.
2) Northern Region Critical Needs: priorities of primarily the northern processing tomato growing regions.
3) Southern Region Critical Needs: priorities of primarily the southern processing tomato growing regions.

Within the statewide and regional needs, critical needs are also grouped as follows:

- General Critical Needs: needs that apply to several categories of pests (e.g., insects, diseases, and nematodes).
- Critical Needs for Insect Pests: needs that are specific to major insect pest problems.
- Critical Needs for Disease Pests: needs that are specific to major disease problems.
- Critical Needs for Nematode Pests: needs that are specific to major nematode problems.
- Critical Needs for Weeds: needs that are specific to major weed problems.
- Critical Needs for Vertebrate Pests: needs that are specific to major vertebrate pest problems.

Within the above groups, needs are also grouped into those that are specific to research, regulations, and education.

## Statewide Critical Needs

### General Statewide Critical Needs

*Research*

1) Develop integrated pest management (IPM) strategies to reduce pest problems, including cultural practices (especially irrigation and fertilization management) and encouraging the establishment of natural enemies. Emphasize multiple management methods rather than reliance predominantly one method.
    - Conduct more research on how to use methods of managing pests that are less strictly regulated, including robotics, cultivation, resistant varieties, etc.
    - Develop integrated pest management tools that can be integrated with economic thresholds.
2) Research the relationship between soil (e.g., soil health indicators, soil and nutrient management practices, moisture) and various pest problems (soil-dwelling insect pests, soilborne diseases, and weeds). Seek funds from the Soil Health Initiative to conduct this research.

3) Develop best management practices particularly for equipment and harvester sanitation (including equipment used during crop rotations) to eliminate the spread of pathogens and weed seeds, especially *Fusarium* pathogens and broomrape seeds.
    - Determine the efficacy of an array of methods for cleaning field equipment, including steam cleaning, pressure washing, and application of chemicals or disinfectants.
4) More research to develop robotic technology for pest management.
    - Develop and determine the efficacy of robotic weed management equipment including machine vision recognition technology (better computer recognition of transplants versus weeds) and especially equipment that will be effective later in the season.
    - Research ways in which robotic technology can be used to diagnose diseases or detect crop health deterioration: detection of plant volatiles that attract pests, chemical cues that indicate disease, and light wavelengths reflected by unhealthy plants (spectral reflectance).
    - Help lower the cost of robotics technology to be more affordable.
5) Improve methods of assessing and maintaining transplant health and vigor prior to planting, including prevention of transplant shock and maintenance of transplant quality when planting is delayed.
6) Identify and optimize chemigation-based application methods and other options that utilize the buried drip irrigation system.
    - Determine if any herbicides applied via chemigation can control broomrape.
    - Determine the effectiveness of insecticides and fungicides (either systemic or nonsystemic) applied through drip chemigation in order to be compliant with spray application restrictions near schools.
        - Especially research the efficacy of drip-applied fungicides that reduce reliance on fumigation with metam sodium.
    - Develop more insecticides and fungicides that can be applied through the drip irrigation system.
    - Evaluate potential of drip-applied rodenticides and repellents; test the efficacy of preplant, drip-applied metam sodium fumigation against rodent pests.
7) Determine the potential of mustard seed biofumigants (active ingredient allyl isothiocyanate, example trade name Dominus) to manage soilborne pathogens, weeds, and nematode pests.
    - Assess the phytotoxicity of mustard seed biofumigation to the tomato crop.
    - Determine whether mustard seed biofumigants reduce soilborne pathogens (e.g., *Fusarium* and *Verticillium*), or increase certain pathogens (e.g., *Sclerotinia*).
    - If effective, determine the proper timing for maximum effectiveness and minimal crop damage.

<u>*Regulatory*</u>

1) Change California Division of Occupational Safety and Health (Cal/OSHA) policies to make the use of autonomous weeding vehicles and other autonomous machinery more feasible.

- Change the requirement that an operator must be within ten feet of an autonomous machine to enable one operator to be responsible for multiple automated weeders (swarm technology).

2) Register pesticides (especially but not limited to fungicides) for chemigation through the drip irrigation system so that it is easier to comply with regulations for pesticide applications near schools.
3) Register insecticides that have long duration of efficacy against pests (especially thrips) and insecticides that can be applied through drip chemigation.
4) Increase the timeliness of registration for new pesticides and uses.

*Education*

1) Update the UC IPM *Integrated Pest Management for Tomatoes* manual to include updated color photos and transplant health assessment and protection (see General Statewide Critical Needs, research need #5).
2) Create or adapt an informational guide or other resources for greenhouse operations and field growers to assess the quality and overall health of transplants prior to planting.
3) Include greenhouse pest management activities in extension publications such as the UC IPM *Pest Management Guidelines: Tomato*.
4) Create a pocket field guide and cell phone app to help growers and pest control advisers identify diseases and insect pests (with higher priority placed on identifying diseases) in the field.

## Statewide Critical Needs for Diseases

*Research*

1) Conduct the research necessary to adopt effective and affordable integrated pest management (IPM) practices for *Fusarium* diseases.
    - To promote decision support, develop accurate and rapid diagnostic procedures for identifying *Fusarium* diseases both in the field and in the lab, including tests for: infected plants, soil (including specific soil sampling instructions), and water.
    - Develop information on the biology and epidemiology of *Fusarium* pathogens, including race 3 of the Fusarium wilt pathogen (*Fusarium oxysporum* f. sp. *lycopersici* race 3), pathogens that cause Fusarium crown rots (*Fusarium oxysporum* f. sp. *radicis-lycopersici*), and *Fusarium falciforme*.
    - Determine the longevity and survival biology of *Fusarium* pathogens. Determine alternate hosts, identify effective crop rotation options (if any), and develop best crop rotation practices.
    - Identify the main ways *Fusarium* pathogens are introduced into fields, especially via irrigation water and harvest equipment, and develop a better understanding of the drivers of unpredictable Fusarium wilt outbreaks.
    - Determine if sanitation of harvest equipment plays a role in reducing inoculum and most effective methods for removing *Fusarium* on harvest equipment (see General Statewide Critical Needs #3 for more information).

- Develop economic thresholds based on the amount of inoculum in the soil (especially for Fusarium wilt), and management strategies to cope with different amounts of inoculum.
- Monitor for the development of a new race of Fusarium wilt (race 4) that breaks host resistance. Identify the conditions under which Fusarium wilt breaks host resistance, including drought stress, salinity, amount of soil inoculum, and other plant stressors.
- Evaluate and rank efficacy of methods to manage Fusarium wilt in processing tomato fields.

2) Develop new, robust resistant varieties as a management tactic for major diseases, especially *Fusarium* diseases, *Tomato spotted wilt virus*, and *Beet curly top virus*.
    - Develop processing tomato varieties with multiple-gene or stacked resistance to diseases (2 or 3 genes minimum), rather than single-gene resistance that is easily overcome by the pathogens.
        - Use the Tomato Genetics Resource Center as a resource for identifying such genes.
3) Monitor the expansion of resistance-breaking *Tomato spotted wilt virus* and determine ways to manage the breaking of host resistance (see #5).
    - Identify the role of planting nonresistant varieties or cultivars in the field to delay or prevent the development of *Tomato spotted wilt virus* strains that overcome host resistance.
    - Develop a field-use quick test to detect resistance-breaking *Tomato spotted wilt virus* (if applicable).
    - Develop cultivars with resistance to the new race.
4) Determine ways to manage the breaking of host resistance for major pathogens such as *Tomato spotted wilt virus*, bacterial speck, and Fusarium wilt. Explore the role of nonresistant varieties or cultivars in reducing the chance that a pathogen will break host resistance, and how the use of these cultivars might be implemented in an integrated pest management approach for these diseases.
5) Develop best management practices for transplant greenhouses to manage diseases that compromise transplant quality, especially integrated pest management (IPM) methods (with an emphasis in sanitation) that successfully prevent and manage bacterial speck and bacterial canker.
6) Investigate the efficacy of seed disinfestation methods to manage seedborne diseases and develop more effective methods if necessary.
7) Develop a quick test to detect *Beet curly top virus* in the field.
8) Develop effective methods to manage diseases that cause premature canopy loss (such as powdery mildew, wilt and rot diseases, and severe bacterial speck and spot), increase the risk of sunburn, and facilitate the development of black mold and other fruit rots.
    - Identify and determine the efficacy of more pesticides for powdery mildew management.
    - Evaluate other methods of preventing sunburn in addition to kaolin clay.
    - Determine the efficacy and proper application timing of kaolin clay for prevention of sunburn, black mold, and fruit rots without damaging the crop.
9) Identify effective approaches to southern blight management.

- Determine the crop stage during which southern blight first infects processing tomato and the conditions that influence infection of processing tomatoes (crop rotations, soil type, amount of sclerotia, etc.).
    - Identify and rate rotational crops that are hosts and nonhosts for southern blight.
- Develop practices to eliminate salt buildup under the drip line and reduce bed top wetness that favors southern blight development.

*Regulatory*

1) Increase state funding for curly top management efforts.
2) Review the current standards for testing tomato seed for pathogens prior to planting in the greenhouse. If necessary, raise standards and develop clearer procedures for testing and quality control (e.g., in terms of amount of seed tested, number of samples tested, sensitivity of testing procedures, retesting treated seed, viability of seed after testing, and guidelines for seed destruction).

*Education*

1) To reduce misdiagnoses and improve the timeliness of disease diagnosis:
    - Teach advisors (both public and private) and growers how to differentiate between each of the different diseases that cause premature vine decline, wilt, and crown rot, including the differences between *Fusarium* diseases, Verticillium wilt, southern blight, bacterial canker, and late blight.
    - Train both public and private diagnosticians in laboratory diagnostic methods.
2) Educate growers on best methods to reduce the salt buildup under the drip line that favors southern blight development.
3) Increase grower understanding of genetically modified organisms (GMOs) and CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology. Stakeholders want to know the difference between these technologies and how CRISPR in particular may assist in the development of new resistant tomato varieties, especially those that are resistant to *tomato spotted wilt virus* or *Fusarium* diseases.
4) Educate greenhouse operations on best sanitation practices to prevent bacterial speck and canker.
5) Educate growers on what diseases are or are not seedborne.

## Statewide Critical Needs for Insect and Invertebrate Pests

*Research*

1) Research the efficacy of alternatives (insecticides and nonchemical methods) to the insecticides for which stakeholders anticipate restrictions or cancellations (e.g., diazinon, malathion, neonicotinoids). Look for alternatives (especially for sucking pests) that have low risk to pollinators.
2) Improve IPM strategies for insect pests such as stink bugs, darkling beetles, and thrips.

- Evaluate insecticides and other management methods that are effective against stink bugs, especially consperse stink bug.
    - Produce insecticides with better coverage; increase the coverage of insecticides that are currently available (especially alternatives to dimethoate, pyrethroids, neonicotinoids, and emulsifiable concentrate formulations).
    - Develop area-wide management strategies that reduce stink bug infestations.
    - Identify natural enemies that attack stink bugs and specific methods to increase their numbers in fields.
- Anticipate problems posed by brown marmorated stink bug and be ready to address infestations if they happen.
- Research proper pesticide application and spray timing to control thrips and prevent tomato spotted wilt virus.

3) Conduct research on effective management of beet leafhopper and prevention of beet curly top virus, to make these problems more manageable in the southern processing tomato growing regions and prevent their spread into the northern growing regions.
4) Better understand the biology, life cycle, and behavior of processing tomato insect pests.
    - Develop predictive models for stink bugs, beet leafhopper, and thrips to determine when they will move into fields.
    - Identify overwintering sites and alternate host plants (including weeds, cover crops, and rotation crops) that increase problems from stink bugs, beet leafhopper and thrips. Incorporate this information into integrated management programs for these pests and vectored diseases.
5) Test alternatives to malathion for control of beet leafhopper.
    - Evaluate insecticides, especially granular insecticides, and products with less potential for drift.
    - Evaluate biological control agents for beet leafhopper.
    - Evaluate kaolin clay as a deterrent for beet leafhopper.

*Regulatory*

1) Register alternatives to neonicotinoids, organophosphates (especially diazinon and malathion), and carbamates. Preferably register options that have less impact on pollinators and natural enemies, but efficacy is the top priority.
2) Provide funding support for the California Department of Food and Agriculture and UC Cooperative Extension to increase research on effective management of beet leafhopper and *Beet curly top virus*.
3) If neonicotinoid insecticides are restricted or eliminated in the future, obtain exemptions for major insect pests for which neonicotinoids are the only effective option (e.g., stink bugs).
4) Register effective insecticides for beet leafhopper.
    - Increase funding to test malathion alternatives.
    - Register systemic insecticides that can be used in surrounding areas (e.g., foothill areas and weeds around fields) that harbor beet leafhopper.

*Education*

1) Conduct outreach and education efforts on the most effective insecticide applications for disease-vectoring insect pests.
2) Educate growers and pest control advisers on alternatives to insecticides (e.g., neonicotinoids) that may be restricted or canceled in the future.
3) Increase outreach to growers about how to manage thrips, including:
    - Known alternative hosts for thrips (including both weeds and crops).
    - Proper timing for thrips sprays.
    - Effective management methods.
4) Educate growers and other stakeholders about the tomato leafminer (*Tuta absoluta*) and prepare the industry to respond to detections or potential introduction of this pest.
5) Educate growers about brown marmorated stink bug and effective management options if this pest becomes a bigger problem in processing tomato.

## Statewide Critical Needs for Weeds

*Research*

1) Develop and identify management methods (including, but not limited to, herbicides) that work for difficult-to-control and perennial weeds, particularly nutsedge and field bindweed.
    - Better understand weed biology and how to influence weed biology for the purposes of weed management, especially methods to break the dormancy of belowground structures (especially field bindweed and nutsedge).
2) Develop effective, affordable methods to eradicate branched broomrape from processing tomato fields, prevent its spread, and manage infestations if it becomes well established in California (see Northern Region Critical Needs for Weeds for more information).
    - Identify effective and practical sanitation methods, especially for eliminating broomrape seed on harvesting equipment (See Statewide General Critical Needs #3).
    - Develop methods to detect branched broomrape and Egyptian broomrape in tomato fields more easily.

*Regulatory*

1) Take necessary measures to eradicate Egyptian broomrape and branched broomrape from processing tomato fields and reduce the financial burden of broomrape infestations.
    - Obtain use exemptions for methyl bromide to eliminate broomrape infestations.
    - Increase state funding for broomrape eradication efforts to a sufficient amount to address current projections of infestation. Make state assistance available to growers, with incentives to encourage growers to report infestations early.

- Adjust crop insurance policies to compensate growers in the case of yield or field loss from broomrape infestations.
- Create a state commission or other statewide effort to prioritize broomrape eradication.
- Consider implementing mandatory reporting of broomrape infestations for all relevant stakeholders (pest control advisers, growers, cooperative extension personnel, etc.).

*Education*

1) Educate growers, pest control advisers, harvesters, and other relevant operations on the importance of taking measures to reduce the spread of broomrape.
    - Educate growers on the importance of reporting broomrape infestations.
    - Educate processors on proper sanitation methods for broomrape and the importance of equipment sanitation to preventing the spread of broomrape.
    - Create specific instructions for how to sanitize vine trainers and harvest equipment the proper way to eliminate the spread of broomrape.
    - Teach growers how to identify both branched broomrape and Egyptian broomrape.
    - Create a certification program for pest control advisers and growers on broomrape identification, stages, scouting, and steps to take in a situation of a positive identification.
    - Develop and disseminate general, statewide distribution maps for broomrape.

**Statewide Critical Needs for Nematode Pests**

*Research*

1) Develop new lines of resistance (including multi-gene and stacked resistance) for resistance-breaking nematodes.
2) Research the potential of soil additives and biological nematicides to control root-knot nematodes.
3) Determine what abiotic conditions (e.g., heat, water quality, salinity) may predispose processing tomatoes to nematode infestations.
4) Identify alternative hosts for root-knot nematodes and explore the potential persistence of root-knot nematodes in fallow fields.
5) Evaluate efficacy of new nematicides like those with active ingredients allyl isothiocyanate (active compound in mustard seed meal), fluensulfone (example trade name: Nimitz), fluopyram (example trade name: Velum One), and fluazaindolizine (example trade name: Salibro) compared to older nematicides.

*Regulatory*

1) Register new preplant fumigants such as allyl isothiocyanate.

2) Register new nematicides such as fluazaindolizine and any relevant biological nematicides.

*Education*

1) Show stakeholders what root-knot nematode populations look like throughout the state, including host-resistant populations and where resistance breakdown is occurring.

## Statewide Critical Needs for Vertebrate Pests

*Research*

1) Research new rodenticide options, particularly for voles and gophers.

*Regulatory*

1) Register any new rodenticides developed and tested for processing tomato (especially for voles and gophers). Add more rodenticide options if second-generation anticoagulants become deregistered.

*Education*

1) Add management information about vertebrate pests to the UC IPM *Pest Management Guidelines: Tomato*.
2) Educate growers on how to maintain drip tape so that it does not get damaged by voles, gophers and ground squirrels.
3) Incorporation of drip tape maintenance (including flushing, chemical cleaning, reducing root intrusion, and issues related to water quality and fertigation or chemigation) into overall integrated pest management (IPM) publications, such as in the UC IPM manual *IPM for Tomatoes* or UC IPM *Pest Management Guidelines: Tomato*.

# Northern Region Processing Tomato Critical Needs

The needs listed here are needs in the northern processing tomato growing region that are in addition to those listed in the statewide critical needs.

## General Northern Region Critical Needs

*Research*

1) Research the use of rotation and cover crops (especially mustards, sunflowers, rice, and other cereals) for pest management, including effect of organic matter on insect and invertebrate pests (e.g., symphylans), weeds, diseases, and seedling pests; timing of cover crop use; proper cover or rotation crop selection for specific pest problems; and phytotoxic effects on tomatoes.
    - Determine the efficacy of mustard rotation crops for weed infestations in organic systems. Assess the risks of phytotoxicity of mustards and mustard seed meal to the tomato crop.
    - Determine whether crop rotation with mustards reduces soilborne pathogens (e.g., *Fusarium* and *Verticillium*) or increases certain pathogens (e.g., *Sclerotinia*).
    - Determine whether crop rotation with rice increases the risk of southern blight or *Fusarium* infection.
2) Research biopesticide efficacy in both transplant and field production, including modes of action, conditions that are most conducive to good efficacy, potential colonization of the crop (in the case of microbial products), equipment maintenance (e.g., accumulation of molasses), proper storage, application rates, resistance prevention, and formulations for tank mix applications (if applicable).
    - Research the above questions especially (but not exclusively) as they pertain to diseases.

*Regulatory*

There are no region-specific critical needs for this category beyond those stated in the General Statewide Critical Needs.

*Education*

1) Educate growers and pest control advisers on the use of crop rotations (mustards, cereals, sunflowers) for pest management, including timing of growing cover crops and proper cover crop selection for specific pest problems (see Research Needs #1 above for more information).
2) Identify and provide growers and PCAs information on ineffective pesticides, tank mixes (e.g., for microbial pesticides and other biopesticides), and application methods, to help reduce costs associated with ineffective applications.

## Northern Region Critical Needs for Diseases

*Research*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Diseases.

*Regulatory*

1) Revise labels for biological products to make it clear how to use the product correctly and include all details necessary to maximize efficacy (see General Northern Region Critical Needs above).
2) Register fungicides that protect against fruit rots (including black mold).

*Education*

1) Educate growers about realistic conditions under which microbial or biological pesticides are effective, including the necessary steps to make them more effective.
2) Increase awareness of processing tomato varieties that are resistant to *Fusarium* pathogens.
3) Increase communication between field growers and greenhouse operations about reducing diseases and other issues associated with transplants.
4) Encourage greenhouse operations to test seeds for pathogens so that growers can anticipate problems and take proper preventive measures.
5) Improve education on *tomato spotted wilt virus* management (see Northern Region Critical Needs for Insects).

## Northern Region Critical Needs for Insect and Invertebrate Pests

*Research*

1) Research and identify integrated pest management (IPM) strategies (especially impacts of water and fertilization management) for insect and invertebrate pests such as wireworms, russet mite, and aphids (in addition to the insect pests mentioned in the Statewide Critical Needs for Insect Pests, Research Needs).
    - Identify effective alternatives to diazinon for wireworm management.

*Regulatory*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Insect and Invertebrate Pests.

*Education*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Insect and Invertebrate Pests.

**Northern Region Critical Needs for Weeds**

*Research*

1) Develop integrated weed management methods (including herbicides) for difficult weeds such as fleabane, horseweed, groundcherries, velvetleaf, nightshades, and glyphosate-resistant ryegrass and sunflowers.
2) Conduct necessary efficacy research to register herbicides as described in the Northern Region Critical Needs for Weeds, Regulatory Needs.
3) Identify environmental conditions and production practices that produce different weed problems, including soil quality and water management, and the efficacy of cultural practices to manage such weeds.
4) Determine effective management practices for broomrape infestations.
    - Determine the efficacy of methyl bromide alternatives (e.g., metam sodium/metam potassium, solarization, conventional herbicides).
    - Identify biological control agents that may attack broomrape and test potential options.
    - Determine or confirm how broomrape spreads from field to field, and ways to prevent its spread.
5) Research management practices (including herbicides) that control nightshades and reduce reliance on the costly practice of hand weeding.
6) Test efficacy of more postemergence herbicides (particularly those that can be sprayed over the top of the crop) and herbicides available for fallow bed weed control.

*Regulatory*

1) Add or expand herbicide registrations.
    - Register more fallow bed and preplant herbicides and increase application options (especially aerial and helicopter applications) to give growers weed control options to use in wet preplant conditions.
    - Explicitly register herbicides for fallow bed management, not just preplant use.
    - Identify and register herbicides that can be used near almond orchards.
    - Register herbicides for difficult weeds such as fleabane, groundcherries, horseweed, nightshades, velvetleaf, and glyphosate-resistant ryegrass and sunflowers.
    - Pursue 24(c) labels or Section 18 exemptions where necessary and possible.
    - Register postemergence herbicides that are safe to apply over the top of the tomato crop to kill late-season weeds.

*Education*

1) Educate growers and pest control advisers on how to reduce herbicide drift. Many of the herbicides registered in processing tomato (e.g., carfentrazone) have drift issues.
2) Conduct outreach to growers and pest control advisers about impacts of soil quality, water management, and other conditions that produce specific weed problems and how to avoid them via cultural practices.
3) Educate growers and pest control advisers on how to reduce and manage glyphosate-resistant weeds (especially ryegrass, fleabane, and sunflower).

**Northern Region Critical Needs For Nematode Pests**

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Nematode Pests.

**Northern Region Critical Needs For Vertebrate Pests**

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Vertebrate Pests.

# Southern Region Processing Tomato Critical Needs

## General Southern Region Critical Needs

There are no region-specific critical needs for this category beyond those stated in the General Statewide Critical Needs.

## Southern Region Critical Needs for Diseases

### *Research*

1) Develop a research group or partnership with University of California Cooperative Extension to address curly top prevention and management, in addition to the research necessary to manage the beet leafhopper vector of *beet curly top virus* (see Southern Region Critical Needs for Insect Pests).
2) Develop host resistance to curly top virus and southern blight. Overcome challenges imposed by introducing southern blight-resistant rootstock into the industry.
    - Research the compatibility of resistant rootstocks and scions to grow at a similar pace.
    - Reduce the barriers to grafting processing tomatoes affordably (e.g., lack of mechanization, amount of greenhouse space).
3) Learn ways to increase beneficial microbes in the soil without increasing pathogenic microbes.
4) Explore whether nematode infestation increases the likelihood of *Fusarium* infection and other diseases (such as corky root rot), as well as the impact of the combination of nematodes and *Fusarium* on yields.
5) Identify the main sources of bacterial speck and bacterial canker in greenhouses.
6) Develop a plan to manage and mitigate damage from *tomato brown rugose virus* to anticipate its potential establishment in California.
    - Determine how the virus spreads and how to reduce its spread.

### *Regulatory*

1) Create a budget specific for studying the relationship between soil health/quality, pathogen loads, and disease pressure.

### *Education*

1) Enhance the relationship between University of California Cooperative Extension and the processing tomato industry to develop new resistant varieties and management methods.
2) Continue meetings and communication about curly top updates.
3) Educate neighbors of processing tomato growers about the impacts of their pest management practices and timing of practices on processing tomato pest pressure (e.g.,

mowing orchard floors). Facilitate better communication between processing tomato growers and their neighbors about planned activities.

4) Do outreach with private tomato breeders to increase awareness of the benefit of stacked resistance.

## Southern Region Critical Needs for Insect and Invertebrate Pests

### *Research*

1) Identify effective control and monitoring methods for garden symphylans.
2) Determine whether applications of systemic insecticides like imidacloprid and cyantraniliprole at or before transplanting are effective against major disease vectors, and whether it is more effective to apply before or after planting.
3) Determine what rotation crops reduce whitefly infestations; determine whether and how whiteflies can survive year-round in the southern region.

### *Regulatory*

1) If there are natural enemies effective against consperse stink bug in other regions, obtain an exemption to bring these natural enemies into California.

### *Education*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Insect and Invertebrate Pests.

## Southern Region Critical Needs for Weeds

### *Research*

1) Develop effective alternatives to glyphosate, especially those that are systemically translocated.
2) Enhance cultivation methods for removing weeds, such as via finger and torsion weeders or robotic technology.
3) Increase efforts to find effective biological control agents for weeds (e.g., research the effectiveness of the herbivorous mite that attacks Russian thistle).

### *Regulatory*

1) Register any effective and viable alternatives to glyphosate, especially systemically translocated herbicides.

### *Education*

1) Educate growers on whether or how natural enemies can be used to manage Russian thistle and other relevant weeds.

## Southern Region Critical Needs for Nematode Pests

*Research*

1) Determine how yields are impacted when infected with both *Fusarium* and nematodes.
2) Conduct a risk assessment for the peach root-knot nematode in processing tomato.

*Regulatory*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Nematode Pests.

## Southern Region Critical Needs for Vertebrate Pests

*Research*

1) Develop and evaluate alternative rodenticide formulations (such as encapsulated rodenticides) with lower toxicity to predators.
2) Determine how to increase the persistence of rodenticides and decrease risk of exposure to workers (e.g., increase the time rodenticide tablets take to become active).
3) Find effective deterrents for gophers and other rodent pests.
4) Test whether any proposed management methods for rodent pests in the field (especially voles) inadvertently attracts rodents to processing plants, and if so, develop mitigation measures.

*Regulatory*

There are no region-specific critical needs for this category beyond those stated in the Statewide Critical Needs for Vertebrate Pests.

*Education*

1) Educate stakeholders about how to reduce the likelihood of food safety problems from vertebrate pests, including preventing salmonella and other foodborne pathogens.

# Foundation for a Pest Management Strategic Plan

The following describes the major pests of processing tomato and their damage, the crop stages when they are a concern, and the main management methods (including organic practices), that are used to manage infestations. For more information, view the *UC IPM Pest Management Guidelines: Tomato*.

## Insect and Other Invertebrate Pests (Not Virus-Transmitting)

### Armyworms

Armyworms (*Spodoptera exigua* and *Spodoptera praefica*) are primarily a pest in the northern growing areas. They tend to infest processing tomato fields later in the season and are most damaging when they enter the fruit. Monitoring for armyworms begins when fruit reach 1 inch in diameter.

Natural enemies commonly provide good control of armyworms. Reduced-risk insecticides such as *Bacillus thuringiensis* (Agree) and methoxyfenozide (Intrepid) also provide good control. Methomyl is used only for severe infestations. In organic fields, azadirachtin (DeBug) is also used for armyworms and other caterpillar pests.

Summary of stage-specific management practices:

- Late Fruit Set, First Red Fruit: Monitor for armyworms, damage, and natural enemies. Apply an insecticide if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of these pests, see: ipm.ucanr.edu/agriculture/tomato/Beet-Armyworm and ipm.ucanr.edu/agriculture/tomato/Western-Yellowstriped-Armyworm.

### Cutworms

Cutworms (primarily *Peridroma saucia* and *Agrotis ipsilon*) are occasionally a problem in the northern growing region. They typically cause damage earlier in the season, while tomato plants are actively growing. After transplanting, they can reduce a stand by clipping transplants at the soil line. Later on, they can also chew irregular holes into developing fruit, especially fruit that is touching the ground.

Weed management and cultivation usually reduce cutworm numbers. Carbaryl (Sevin) or spinosad (Seduce) baits are usually effective if insecticides are necessary.

Summary of stage-specific management practices:

- Preplant: Remove weeds in and around the field, cultivate soil.

- Planting to Prebloom: Monitor for cutworms and their damage and apply insecticide bait if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines*).
- Late Fruit Set to First Red Fruit: Monitor for cutworm damage by examining fruit that touches the soil, apply insecticide if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines*).

For more information on identification, monitoring, and management of these pests, see: ipm.ucanr.edu/agriculture/tomato/Cutworms.

**Darkling beetles**

Darkling beetles (*Blapstinus* species) infest processing tomato in various areas throughout the state. They damage the crop early in the season, from planting to prebloom. Darkling beetles chew the tender stem tissue of young transplants. Unlike cutworms, they chew the stem only partially, therefore the chewing does not clip the transplants completely. However, darkling beetle chewing causes the plant to collapse several days or several weeks after they feed on the plant.

One of the key management practices for preventing infestations is allowing crop residue and other organic matter to decompose completely prior to planting. The complete decomposition of organic matter may be assisted by preplant cultivation. Rotating to cover crops generally increases beetle infestations, but cotton and safflower rotations are believed to reduce their numbers in the southern growing regions. Organic production may also maintain one or more water-filled ditches along the field edges to reduce beetle movement into the field from surrounding areas.

In conventional fields, carbaryl (Sevin) bait, diazinon, and esfenvalerate (Asana, applied via sprinkler chemigation) are the primary insecticides growers use for managing heavy infestations. The timing of insecticide application depends on the insecticide. For example, diazinon must be applied before planting, while esfenvalerate can be applied after planting.

Baits have been ineffective for darkling beetles in several situations in the southern region; however, it is possible that bait quality or application timing affected efficacy under those circumstances.

Summary of stage-specific management practices:

- Preplant: Cultivate soil and allow organic matter from the previous crop and weeds to completely decompose before planting. If necessary, apply insecticide to manage darkling beetles (see above text).
- Planting to Prebloom: Monitor for darkling beetles and damage and apply insecticide if necessary (see above text and Efficacy Tables). Maintain water-filled ditches along field edges in organic production.
- Postharvest: In the southern growing regions, rotate to cotton or safflower if darkling beetles were a problem during the processing tomato season.

## **Garden symphylan**

Garden symphylan (*Scutigerella immaculata*) is an occasional early-season pest of processing tomato throughout the state. It chews and damages seedlings for several weeks after transplanting. This pest is a recurring and persistent problem in specific fields or smaller areas within the fields that are affected.

A common practice for preventing damage from symphylans is to cultivate soil and allow organic matter in the soil to decompose completely before planting. However, organic processing tomato fields with high amounts of organic matter in the soil may have few problems with this pest, so the effectiveness of reducing organic matter may be somewhat uncertain. Planting later in the spring when the soil is warmer reduces symphylan damage for some stakeholders, but others who use this practice may still experience high symphylan damage.

During the season, garden symphylan may be monitored by digging around weakened transplants. Other cultural practices may include avoiding legumes as a rotation crop, as legumes seem to increase symphylan infestations in the subsequent crop. Some stakeholders in the southern region indicated that higher moisture seems to make processing tomato more resilient to infestations.

In conventional fields, a soil application of diazinon or a shank application of zeta-cypermethrin (Mustang) is used before planting in fields where garden symphylan is a persistent problem. Because low numbers of garden symphylan can damage the crop, insecticides are applied if any number of symphylans are found. Applying insecticide after symphylans damage the crop may be ineffective.

Summary of stage-specific management practices:

- Preplant: Cultivate soil, allow organic matter to completely decompose before planting. Apply insecticide in fields or parts of the field that are regularly damaged by garden symphylan (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Planting to Prebloom: Monitor for symphylan by digging around weakened transplants.
- Postharvest: Avoid planting legumes as a rotation crop.

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Garden-Symphylans.

## **Lygus bugs**

Lygus bugs (*Lygus hesperus* and other *Lygus* species) are occasional late-season pests in whole-peel processing tomato in the northern region. Their feeding on fruit causes some of the fruit wounds to split and dry. Damage tends to be worse in tomatoes grown near beans or safflower.

Removing weeds in and around fields is important to preventing lygus infestations. When insecticides are necessary, growers typically use pyrethroids such as fenpropathrin (Danitol).

Systemic insecticides such as neonicotinoids (Admire, Assail, or Venom) or flonicamid (Beleaf) also reduce lygus infestations. Managing lygus in nearby safflower can also be important to preventing infestations in processing tomato (see the Safflower Pest Management Strategic Plan for more information).

Summary of stage-specific management practices:

- Bloom to Early Fruit Set: Remove weeds in and around the field and monitor for lygus bugs.
- Late Fruit Set, First Red Fruit: Remove weeds in and around the field, monitor for lygus bugs, and apply insecticides if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Lygus-Bugs.

## Potato aphid

Potato aphid (*Macrosiphium euphorbiae*) is a problem in the northern region during the later stages of growth, beginning at late fruit set and continuing through fruit ripening. This pest has become less of a problem over the last decade, but still causes sporadic damage in the northern region. Feeding by high numbers of potato aphid can distort and damage stems and leaves, as well as reduce plant vigor. Their honeydew causes sooty mold to develop on both foliage and fruit.

Biological control by naturally occurring natural enemies can reduce potato aphid numbers and damage. Potato aphid must also be monitored for 6 to 8 weeks before harvest (see *Pest Management Guidelines: Tomato*).

Systemic insecticides (such as Admire or Assail) are used to manage high potato aphid numbers. Pyrethrins (PyGanic), azadirachtin (DeBug), and insecticidal soaps (M-Pede) and oils (Proud, Ecotrol) may be used to manage this pest in organic processing tomato.

Summary of stage-specific management practices:

- Late Fruit Set, First Red Fruit: Monitor for potato aphid and natural enemies. Apply insecticides if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Potato-Aphid.

## Stink bugs

Stink bugs are damaging late-season pests of processing tomato (especially whole-peel tomatoes) statewide. They cause more damage to processing tomato in the southern growing region, where they can reduce marketable yields by up to 40%. Stink bugs cause damage from late fruit set through fruit ripening. Consperse stink bug (*Euschistus conspersus*) is currently the most damaging species, but southern green stink bug (*Nezara viridula*) can also cause damage. Growers are also concerned about future infestations by the invasive brown marmorated stink bug (see Pests of Future Concern), since this pest has become a problem in other California crops.

Stink bug feeding causes fruit to become callused and discolored. Occasionally, their feeding on mature fruit also facilitates secondary infection by yeasts, which causes the fruit to develop a severe rot. If damage occurs during earlier stages of fruit development, the fruit completely disintegrates, causing substantial yield loss.

Thresholds are generally not used for stink bugs because very low numbers can quickly damage the crop. Pheromone lure traps placed in fields with recurring consperse stink bug problems assist with early detections of the pest but do not reduce pests below damaging numbers. Several natural enemies attack stink bug eggs, but they have not eliminated the need to apply insecticides. Removing weeds that are especially attractive to stink bugs is an important component of stink bug management. Weeds that are especially important to remove include little mallow (*Malva parviflora*), Russian thistle (Salsola spp.), and mustards such as wild radish (*Raphanus raphinastrum*).

Insecticides are regularly used for stink bug management but do not always provide sufficient enough control to avoid economically significant losses. Current insecticides are generally much less effective than endosulfan (Thiodan) and emulsifiable concentrate formulations that are no longer available. The most common insecticides currently used for stink bugs include dinotefuran (Venom), lambda-cyhalothrin (Warrior), and dimethoate. Clothianidin (Belay), imidacloprid (Admire), and methomyl (Lannate) have also been used for stink bug control in tomato but are generally less effective. Trials conducted by UC Cooperative Extension (Fresno County) suggest that control is best when a neonicotinoid and pyrethroid (especially Warrior) are tank mixed.

Good coverage is critical for stink bug control but is difficult to achieve. Stink bugs also spend a portion of each day at or below the soil surface, making it more difficult to reach all stink bugs with insecticide sprays. Stink bug control tends to be better when insecticides are applied with an air-assisted sprayer. Late-season applications can reduce stink bugs, but it is critical to manage the pest earlier in the season to reduce economic losses from their damage. Late-season applications are much less ideal than earlier management action.

Harvesting as soon as possible is a good strategy to avoid additional stink bug damage and rot from yeasts, but this strategy is not always possible due to predetermined arrangements with processors.

Summary of stage-specific management practices:

- Preplant: Monitor for consperse stink bugs in overwintering habitat (e.g., riparian areas) using lure traps. Manage weeds that attract stink bugs (see above text).
- Planting to Prebloom: Apply insecticide for stink bugs if they are detected in the field.

- Bloom to Early Fruit Set: Monitor for stink bugs in tomato fields, either with pheromone traps or with beating sheets and trays, to detect stink bugs early. Apply insecticide for stink bugs if they are detected in the field.
- Late Fruit Set, First Red Fruit: Monitor for stink bugs and apply insecticides when they are detected (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Harvest: Harvest as soon as possible to avoid additional damage from stink bugs and secondary yeast infections (see above text).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Stink-Bugs.

**Tomato fruitworm**

Tomato fruitworm (*Helicoverpa zea*) is a common late-season pest (late fruit set through harvest) in the northern growing regions. They chew and enter the fruit, causing it to ripen prematurely and damaging it with feces and cast skins.

Natural enemies can be released to attack fruitworm eggs, but this is not a common practice due to its high cost. Monitoring for adults and eggs begins in August and treatment thresholds are used to make management decisions.

Insecticides used for tomato fruitworm are usually those that have reduced environmental impact, such as *Bacillus thuringiensis* (DiPel), spinosad (Entrust, Success), and insect growth regulators (such as Intrepid). In organic production, azadirachtin (DeBug) is used for this pest in place of conventional insect growth regulators.

Summary of stage-specific management practices:

- Late Fruit Set, First Red Fruit: Monitor for fruitworm eggs and small larvae. If necessary, apply insecticides (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*) or release natural enemies (if feasible) based on treatment thresholds.

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Tomato-Fruitworm.

**Tomato russet mite**

Tomato russet mite (*Aculops lycopersici*) is a problem in the northern growing region, from late fruit set through fruit ripening. Its feeding causes the leaves to desiccate. Tomato russet mite feeding can severely dessicate tomato plants, exposing the fruit to excess sunlight and increasing the risk of sunburn and fruit rots. The mite can reduce yield if it is not controlled.

Management options are limited for this pest. Management practices typically involve the application of sulfur dust or abamectin (Agri-Mek).

Summary of stage-specific management practices:

- Late Fruit Set, First Red Fruit: Monitor for tomato russet mite and apply miticides if damage is spreading (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Tomato-Russet-Mite.

## Whiteflies

Whiteflies (*Bemisia tabaci* and *Trialeurodes vaporariorum*) are occasionally an issue in the southern growing regions and may cause damage from bloom through fruit ripening. The main way they damage the crop is by causing delayed and uneven ripening of the fruit. They also produce copious amounts of honeydew that favor the development of sooty mold.

Successful management of whiteflies heavily depends on distance from cotton fields and other major whitefly plant hosts. Whiteflies are usually not a major pest if processing tomato is not planted near cotton. Planting early can also help to avoid damage, although planting date is not often solely under the grower's control due to contracts with processors.

Weed management, especially the persistent removal of field bindweed, removes whitefly alternate hosts. Monitoring for whiteflies is also important in fields with regular infestations.

Insecticides such as buprofezin (Courier), pyriproxyfen (Knack), and systemic insecticides (Admire, Assail, Venom, Sivanto) are used to manage whiteflies. Natural enemies attack whiteflies but may not be effective enough to prevent damage.

Summary of stage-specific management practices:

- Preplant: Avoid planting processing tomato near cotton, remove weeds (especially field bindweed) in and around the field.
- Planting to Prebloom: Plant early, remove weeds within and around the field (see above text).
- Bloom to Early Fruit Set, Late Fruit Set, First Red Fruit: Remove field bindweed and other weeds in and around the field, monitor for whiteflies, and apply insecticides if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Whiteflies.

## Wireworms

Wireworms (*Limonius* spp.) are early-season pests primarily in the northern growing regions. They damage and kill transplants for the first several weeks after planting. They can also chew through 5-mil drip tape, though most processing tomato fields are irrigated with thicker drip tape that is more difficult for wireworms to damage.

Management of wireworms in organic production requires good use of cultural practices, such as cultivating soil before planting and planting when the soil is warm to reduce infestations. Diazinon is the primary conventional insecticide used to manage wireworms and must be applied before planting.

Summary of stage-specific management practices:

- Preplant: Cultivate or till soil and install thicker drip tape that cannot be damaged by wireworms. Apply insecticide to the soil if wireworms are causing damage (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Planting to Prebloom: Plant when soil is warm.

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Wireworms.

## Virus-Transmitting Insect Pests

### Beet leafhopper

Beet leafhopper (*Circulifer tenellus*) is a primarily a problem in the southern growing regions, though there is concern that it may also become a problem in the northern regions. Beet leafhopper damages processing tomato by transmitting *Beet curly top virus*. It overwinters in the foothills near processing tomato fields and moves through fields during the season, especially after the cover crops in nearby orchards are mowed. It transmits the virus as it moves through the field. High beet leafhopper numbers may be one of the main drivers of increasing insecticide applications in processing tomato over the past several years.

Control of beet leafhopper using insecticides can be very difficult, since the insects do not reproduce in the crop nor remain established in the crop. The California Department of Food and Agriculture (CDFA) currently monitors beet leafhopper numbers in relevant foothill areas and sprays insecticides for them to prevent the spread of curly top virus. Malathion provides consistent control of leafhoppers that move into the field, though it is also highly toxic to beneficial insects. Other insecticides can be effective, but their efficacy is still not comparable to malathion. There is concern about the potential deregistration of malathion in California and how it would impact beet leafhopper and *Beet curly top virus* management.

Red beets have been used successfully as trap crops for beet leafhopper, but sugarbeet and safflower are much less effective. Maintaining a high crop density also helps reduce damage from this pest. Managing beet leafhopper in nearby safflower may also be important to reducing infestations in processing tomato.

Summary of stage-specific management practices:

- Preplant: (California Department of Food and Agriculture only) Monitor and apply an insecticide to foothill areas where beet leafhopper overwinters.
- Planting to Prebloom: Maintain high plant density, monitor and manage beet leafhopper in trap crop (if used), and apply malathion if beet leafhopper is present.
- Bloom to Early Fruit Set: Maintain high plant density and apply malathion if beet leafhopper is present (if application amounts have not reached the label limit).
- Postharvest: (California Department of Food and Agriculture only) Monitor and apply an insecticide to foothill areas where beet leafhopper overwinters.

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Beet-Leafhopper.

### Green peach aphid

Feeding damage by green peach aphid (*Myzus persicae*) is sometimes a problem in processing tomato throughout the state. Green peach aphid feeding primarily becomes a problem when it transmits *Alfalfa mosaic virus*.

Green peach aphid can be an issue for the first several weeks after transplanting, especially if tomato is planted after an alfalfa rotation, or if tomato fields are near an alfalfa field. Avoiding these conditions is the main way to reduce green peach aphid infestations and prevent alfalfa mosaic. However, alfalfa mosaic is usually not serious enough to warrant this. Avoiding planting near alfalfa also may not be possible in areas with a substantial number of alfalfa plantings.

Insecticides are usually not necessary for green peach aphid. Azadirachtin (DeBug) is occasionally used for green peach aphid management. Neonicotinoids applied for management of other major insect pests tend to also control green peach aphid. While insecticides kill aphids, they do not prevent the transmission of *Alfalfa mosaic virus* because the aphids ingest the insecticide while feeding, and quickly transmits the virus before the ingested insecticide takes effect.

Summary of stage-specific management practices:

- Preplant: Avoid planting processing tomato near alfalfa fields, if necessary and possible.
- Planting to Prebloom: In very rare cases, apply a foliar insecticide if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Green-peach-aphid.

## Thrips

Thrips (primarily western flower thrips, *Frankliniella occidentalis*) are a major problem statewide and can cause damage from planting up to early fruit set. They damage processing tomato by vectoring *Tomato spotted wilt virus*.

To minimize thrips infestations, it is important to avoid planting processing tomato near other hosts of western flower thrips. Though western flower thrips has many hosts, the most problematic ones are radicchio fields, greenhouses with ornamental plants, and weedy orchards (e.g., those that have high amounts of blooming rough-seeded buttercup). Other management practices include host-free periods and possibly delaying planting until after nearby crop hosts are harvested (though this is often not possible based on contracts with processors). Weeds (especially little mallow, prickly lettuce, and sowthistles) should be removed in and around the field to reduce attraction to thrips.

Insecticides are often necessary even when cultural practices are used. Increases in tomato spotted wilt in recent years has increased the need for insecticide applications for thrips. Insecticides are generally sprayed for thrips when tomato spotted wilt appears in fields. However, there are also concerns that this application timing does not substantially reduce the spread of the virus. The most commonly used insecticides include dimethoate, malathion, methomyl (Lannate), pyrethroids (e.g., Warrior, Baythroid), spinetoram (Radiant), and spinosad (Success or Entrust). In organic production, azadirachtin (DeBug) and spinosad (Entrust) may be used to manage thrips.

Summary of stage-specific management practices:

- Preplant: Avoid planting processing tomato near greenhouses, raddichio, or weedy orchards. Remove weeds in and around the field.
- Planting to Prebloom, Bloom to Early Fruit Set: Remove weeds in and around the field. Monitor for thrips and apply insecticides if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato* for more information).

For more information on identification, monitoring, and management of this pest, see: ipm.ucanr.edu/agriculture/tomato/Thrips.

# Viruses

### *Alfalfa mosaic virus*

This disease can sometimes be an issue in the northern growing regions, though damage is typically limited. There are two strains—the yellow-mosaic strain and the necrotic strain. The yellow-mosaic strain causes striking yellow mosaic patterns to develop on the leaves of the plants. The necrotic strain causes leaf, stem and fruit tissue to die in patterns similar to *Tomato spotted wilt virus*. Plants are less likely to recover from the necrotic strain. The spread of the virus is usually limited because its vector (green peach aphid) does not remain the crop for long periods of time and does not persist in the warmer temperatures that are prevalent during the growing season.

The only effective way to manage alfalfa mosaic is to avoid planting near alfalfa. This is usually not necessary and may not be possible in areas with a substantial number of alfalfa plantings. Insecticides that target green peach aphid do not prevent or reduce alfalfa mosaic.

Summary of stage-specific management practices:

- Preplant: If necessary and possible, avoid planting near alfalfa if alfalfa mosaic has been a major problem in the field.

For more information on identification, monitoring, and management of this virus, see: ipm.ucanr.edu/agriculture/tomato/Alfalfa-Mosaic.

### *Beet curly top virus*

*Beet curly top virus* causes tomato plants to become stunted and discolored. Infected plants may die. Though this virus is primarily a problem in the southern growing regions, there is concern that the virus will also become more significant in the northern growing regions.

*Beet curly top virus* is managed almost entirely by managing beet leafhopper, but removing weed hosts (especially plantains, filarees, nettleleaf goosefoot, lambsquarters, and Russian thistle) is another important component of preventing its introduction into the field. There are currently no processing tomato cultivars that are resistant to virus.

Summary of stage-specific management practices:

- Preplant: Manage weed hosts of the virus (see above) and manage beet leafhopper in the foothills.
- Throughout the season: Manage weed hosts of the virus and manage beet leafhopper.

For more information on identification, monitoring, and management of this virus, see: ipm.ucanr.edu/agriculture/tomato/Curly-Top.

### *Tomato spotted wilt virus*

*Tomato spotted wilt virus* causes distinct necrotic brown or yellow spots to form on tomato leaves. It also causes fruit discoloration. This virus is a major concern for processing tomato throughout the state.

Resistant varieties have prevented damage from tomato spotted wilt for a long time. However, they are becoming less effective in recent years as the pathogen has begun to overcome host resistance. A resistance-breaking strain of *Tomato spotted wilt virus* has been detected in several counties (Fresno, Merced, Kern, and Kings counties), and there is concern that this strain will spread to other processing tomato growing areas.

Managing thrips is one of the most important practices for preventing this disease. In addition to managing thrips and planting resistant varieties, it is also important to manage weed hosts of *Tomato spotted wilt virus*. Sowthistles (both annual and perennial) are especially important hosts to eliminate.

Summary of stage-specific management practices:

- Preplant: Manage weed hosts of *Tomato spotted wilt virus*, select varieties that are resistant to the virus, and plan to plant away from areas that harbor thrips.
- Planting to Prebloom, Bloom to Early Fruit Set: Manage thrips and manage weed hosts of *Tomato spotted wilt virus*.

For more information on identification, monitoring, and management of this virus, see: ipm.ucanr.edu/agriculture/tomato/Tomato-Spotted-Wilt.

### ***Tomato yellow leaf curl virus***

*Tomato yellow leaf curl virus* was first detected in Imperial County in 2007, but due to certain climatic conditions and regulatory restrictions, it has not spread to other areas. Though it has not been declared eradicated from California, it has become less of a concern with its successful containment. Growers remain vigilant about managing its insect vector (the sweetpotato whitefly), particularly in the southern growing regions, where whitefly infestations are more common. In addition to tomato, it also infects beans, some ornamental plants, and various weeds.

Summary of stage-specific management practices:

- Throughout the season: Manage whiteflies.

For more information on identification, monitoring, and management of this virus, see: ipm.ucanr.edu/agriculture/tomato/Tomato-Yellow-Leaf-Curl.

# Bacterial and Fungal Diseases

## Alternaria stem canker

Alternaria stem canker (*Alternaria alternata* f. sp. *lycopersici*) is occasionally a problem in the southern growing region. This disease causes dark cankers to form on stems, leaves and fruit. It can kill tomato plants if it is not managed.

Resistant varieties are typically used to prevent Alternaria stem canker infection. Applications of pesticides that control black mold also help manage disease.

Summary of stage-specific management practices:

- Preplant: Select varieties resistant to Alternaria stem canker.
- Bloom to Early Fruit Set, Late Fruit Set, First Red Fruit: Monitor for Alternaria stem canker and apply a fungicide if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Alternaria-Stem-Canker.

## Bacterial canker

Bacterial canker (*Clavibacter michiganensis* pv. *michiganensis*) can be a problem in some years. It tends to be a greater issue in the southern growing regions. This disease can cause symptoms on leaves (drying, yellowing, wilting, spotting, curling), stems (poor growth, cracking and wilting) and fruit (raised, yellow or brown spots with a surrounding halo). Extensive leaf loss and fruit damage can reduce yields.

Key management practices for bacterial canker must take place in the greenhouse, including using pathogen-free seed, disinfecting hoses and benches, and steaming transplant trays. It is also important to avoid working in the field when infected plants are wet to avoid spreading the pathogen.

Bactericides may be applied when conditions favor the development of bacterial diseases, but options are limited to copper (Kocide) and mancozeb (Dithane).

Summary of stage-specific management practices:

- Preplant: (Greenhouse operations) Practice good sanitation in greenhouses, including disinfecting hoses and benches and steaming transplant trays.
- Planting to Prebloom, Bloom to Early Fruit Set, Late Fruit Set: Avoid working in the field when diseased plants are wet. Apply copper and mancozeb when conditions favor disease (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Bacterial-Canker.

## Bacterial speck

Bacterial speck (*Pseudomonas syringae* pv. *tomato*) is a major early-season disease of processing tomatoes statewide, and few effective options exist for its management. This disease causes dark brown or black lesions on leaves, stems and fruit. It commonly becomes a problem in cool, wet spring conditions. Planting may be delayed until conditions are warmer to prevent bacterial speck, though this may not be possible due to established contracts. The disease may become more severe when vines are large and dense, because this creates humid conditions with poor air circulation.

Bacterial speck is a particular challenge because transplants are commonly infected in the greenhouse before they are delivered to the field. It is a common perception in the industry that management in the greenhouse must be improved to prevent disease in the field. Pathogen-free seed, steaming transplant trays, and disinfecting benches and hoses can help reduce speck, but it is unclear if these methods are regularly used.

The primary means of managing this disease is via prevention. For many years, resistant varieties were used to manage this disease. Since the pathogen has broken host resistance, resistant varieties are no longer effective. Prevention may involve removing solanaceous weeds that may harbor the pathogen, as well as avoiding work in the fields when the soil or plants are wet. In organic processing tomato, providing enough space between transplants at planting may also help prevent this disease by enabling adequate air circulation in the canopy at later stages.

Preventive bactericides are also used in conventional processing tomato, but few bactericides are available and effective. Copper (Kocide) and mancozeb (Dithane) are applied together as a preventive treatment; copper on its own is not as effective.

Summary of stage-specific management practices:

- Preplant: Delay planting until weather is warm and dry, if possible. Remove solanaceous weeds. Use sanitation in greenhouse operations to prevent infection (see bacterial canker).
- Planting to Prebloom: Remove solanaceous weeds. Provide adequate space between transplants in organic processing tomato. In conventional processing tomato, apply copper and mancozeb when conditions favor the development of bacterial speck (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Bacterial-Speck.

## Bacterial spot

Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*) has not been as prevalent in processing tomato as bacterial speck and bacterial canker, but it can co-occur with them especially in the southern region. Bacterial spot develops under warm, humid or wet conditions. It causes lesions to form on leaves and fruit. Management for bacterial spot is the same as bacterial canker and bacterial speck.

Summary of stage-specific management practices: see bacterial canker and bacterial speck.

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Bacterial-spot.

## Corky root rot

Corky root rot (*Pyrenochaeta lycopersici*) is occasionally a problem. In recent years, it has more frequently become an issue in the northern growing regions due to cool conditions early in the season. Corky root rot causes roots to appear corky. Banded, brown lesions may also appear on larger roots. Infected plants grow more slowly and may be stunted. Though this disease does not usually kill plants, slower crop growth and stunting that result from the disease can reduce yields.

Fumigation with metam sodium (Vapam) or metam potassium (K-Pam) is currently the only management option for this disease.

Summary of stage-specific management practices:

- Preplant: Fumigate soil with metam sodium or potassium if corky root rot has been a previous problem in the field (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Corky-Root-Rot.

## Fusarium crown and root rot

Fusarium crown and root rot (*Fusarium oxysporum* f. sp. *radicis-lyopersici*) is an issue in processing tomato throughout the state, although it is less prevalent than Fusarium wilt and *Fusarium falciforme*. It can show up any time from bloom to late fruit set. It causes leaves to turn yellow and later die. The roots and stem (up to 1 foot above the soil line) may also be discolored or have visible lesions. This disease can cause tomato plants to wilt, become stunted, and die. This disease is often misdiagnosed as Fusarium wilt because diagnostic tests identify the pathogen only down to the species level, rather than subspecies or race.

Crop rotation and reducing crop residue in the field before planting may be effective for Fusarium crown and root rot. In northern growing regions, management includes rotation to wheat or sunflower to reduce inoculum, but it is uncertain if this practice is effective. Proper irrigation is also considered important to preventing the development of this disease.

Summary of stage-specific management practices:

- Preplant: Allow residue from the previous crop to decompose completely before planting.

For more information on identification, monitoring, and management of this disease, see: [ipm.ucanr.edu/agriculture/tomato/Fusarium-Crown-and-Root-Rot](ipm.ucanr.edu/agriculture/tomato/Fusarium-Crown-and-Root-Rot).

## Fusarium foot rot

Fusarium foot rot (*Fusarium solani* f. sp. *eumarti*) is believed to be a problem in the northern region. It causes damage at the late stages of crop growth. Fusarium foot rot can cause leaves to turn yellow, wilt, shrivel and die, but tends to have more minor impact than the other Fusarium diseases. Symptoms often appear similar to viruses such as alfalfa mosaic or tomato spotted wilt. A dark brown lesion may also be present on one of the main roots. It is possible that tomato plants or fields believed to be infected with Fusarium foot rot have actually been infected with *Fusarium falciforme*, since this pathogen produces similar symptoms and has been identified only recently.

There are few to no management methods available for this disease. Sanitation is considered an important preventive practice. It is unclear which sanitation methods most effectively eliminate the pathogen.

Summary of stage-specific management practices:

- Planting to Prebloom, Bloom to Early Fruit Set: Clean field equipment to avoid spreading the disease.

For more information on identification, monitoring, and management of this disease, see: [ipm.ucanr.edu/agriculture/tomato/Fusarium-Foot-Rot](ipm.ucanr.edu/agriculture/tomato/Fusarium-Foot-Rot).

## *Fusarium falciforme*

*Fusarium falciforme* is a relatively new pathogen of processing tomato that has the potential to be misdiagnosed as other diseases of processing tomato (particularly Fusarium wilt and Fusarium crown and root rot). It has been detected in both the northern and southern growing regions, with several detections in Yolo County, Fresno and Kings counties, Merced County, San Joaquin County, and Sutter County over the last few years.

Infection with *Fusarium falciforme* causes foot root, stem rot, and rapid vine decline in processing tomato. The disease starts off with minor speckling on the leaves that looks similar to *Tomato spotted wilt virus*. The inner stem also develops a vascular discoloration (or stem rot). The disease causes the leaves to die, eventually affecting the entire canopy. Symptoms develop very quickly, and the entire plant can collapse within two to three weeks. Symptoms develop no earlier than 45 days after planting, and whole-plant collapse begins to occur soon afterward (60 days after planting). Premature vine decline from this disease also increases sunburn of the fruit, as well as fruit rot infection. The overall damage from *Fusarium falciforme* has been found to reduce yields by as much as 35%, typically with higher yield losses in tomatoes that have higher amounts of vine decline.

Some cultivars are severely impacted by *Fusarium falciforme* infection, while others are less affected. However, the susceptibility of more tolerant processing tomato cultivars can also vary by region, and cultivars that are less susceptible still develop some amount of vine decline, and all cultivars develop similar amounts of stem rot.

The potential for *Fusarium falciforme* to become well established in processing tomato fields is a major concern for yields. There are currently no known management options for this disease. Although some cultivars are more susceptible than others, no specific cultivars have been marketed to be resistant or tolerant of this pathogen. Though little is known about how crop rotation can affect this pathogen, several rotation crops used in processing tomato growing areas (e.g., safflower, sunflower, and corn) have also been found to develop stem rot when the pathogen is present. Drought stress and certain compost amendments may worsen this disease.

**Fusarium wilt**

Fusarium wilt (*Fusarium oxysporum* f. sp. *lyopersici*) is one of the primary issues in processing tomato throughout the state. It can damage the crop any time from bloom to harvest. In the southern growing regions, management of Fusarium wilt is critical to maintain optimal yields even when other major diseases, such as bacterial speck, *Beet curly top virus*, and *Tomato spotted wilt virus*, are well managed. Infected plants usually die. Yields can be greatly reduced in fields that are affected by Fusarium wilt.

Fusarium wilt is also commonly misdiagnosed. It currently takes several weeks to diagnose in the laboratory, which is longer than growers can afford to wait when crop damage is spreading. The disease has also been mistaken for Fusarium crown rot, bacterial canker, and Verticillium wilt. Distinguishing the Fusarium wilt pathogen from the Fusarium crown rot pathogen is also difficult, because current diagnostic tests only identify the pathogen at the species level (not subspecies, race, or other critical identities that affect management options). Fusarium wilt looks very similar to *Fusarium falciforme* in the field and develops at least 45 days after planting tomatoes. Many fields have been found to be infected with both pathogens.

It is speculated that the Fusarium wilt pathogen is introduced into fields via irrigation water, because some fields have become infected with Fusarium in the first season of processing tomato after more than two decades with nonsolanaceous crops. It is unknown how long the pathogen persists in the field after it is detected, nor is it known how many crops may serve as cryptic hosts of the pathogen (meaning that the pathogen can colonize the plant without the plant expressing any symptoms of infection). In addition to tomato, the pathogen is currently known to colonize melons, cotton, sunflower, onions, and other crops. Weeds may also host the Fusarium wilt pathogen, but this has not been thoroughly investigated. There are also concerns that Fusarium wilt race 3 is breaking host resistance (developing into a race 4). However, thus far there have been no detections of a race 4 in processing tomato. It is also possible for Fusarium wilt race 3 to develop on resistant cultivars when the crop is under stress.

Resistant varieties (with single-gene resistance) have been the primary method used to manage this disease. Crop rotation and reducing crop residue in the field are not considered effective management practices for Fusarium wilt. In the northern growing regions, fields are commonly rotated to sunflowers and wheat, but it is uncertain whether this practice is effective. Preplant soil fumigation with metam potassium can help manage this disease but does not eliminate the pathogen or prevent crop infection entirely. However, metam is also a restricted use pesticide that requires a permit and is also costly to use.

Managing root-knot nematodes is considered an important preventive practice for Fusarium wilt because it is reported that nematode damage breaks host plant resistance to Fusarium. Sanitation may also be an important practice, but it is unclear whether sanitizing field equipment effectively reduces Fusarium and which sanitation methods most effectively eliminate the pathogen.

Few management options are available for this disease and no fungicides are used.

Summary of stage-specific management practices:

- Preplant: Select varieties resistant to Fusarium wilt. Manage root-knot nematodes if they have previously been a problem or use nematode-resistant varieties. Consider soil fumigation with metam potassium if the field was previously damaged by Fusarium wilt.

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Fusarium-Wilt.

**Fruit rots**

Fruit rots include black mold (*Alternaria alternata*), water molds (*Pythium* spp.), and gray mold (*Botrytis cinerea*). These diseases are a late-season issue in all growing areas from fruit ripening through harvest.

Fruit rots are generally managed by reducing fruit contact with water, reducing sunburn to the fruit, and harvesting in a timely manner. Specific practices may include keeping beds dry, vine trimming, and reducing plant density to increase air circulation. Maintaining a strong canopy reduces sun exposure to the fruit and reduces the likelihood of fruit rot development. This is achieved by maintaining healthy plants throughout the season. Reducing damage from defoliating diseases such as bacterial canker and powdery mildew is also crucial to prevent fruit rot development.

Fungicides such as chlorothalonil (Bravo), azoxystrobin (Quadris), or a premix of fluxapyroxad and pyraclostrobin (Priaxor) are commonly used to manage black mold for late-season harvests (in September and October). Fungicide application for these diseases (especially black mold) are made typically if harvest occurs later than ideal or if the fruit will be exposed to wet weather conditions. Kaolin clay (Surround) may be applied late in the season to prevent sunburn and reduce the risk of fruit rots, especially if harvest is planned to occur later than ideal.

Summary of stage-specific management practices:

- Planting to Prebloom, Bloom to Early Fruit Set: Manage defoliating diseases such as bacterial canker to reduce the risk of fruit rot development later in the season.
- Late Fruit Set: Trim vines to increase air circulation, keep beds dry, maintain a strong canopy cover. Manage defoliating diseases (especially powdery mildew) to reduce the risk of fruit rot development.
- First Red Fruit: Keep beds dry, manage defoliating diseases to reduce the risk of fruit rot development. If necessary, apply a fungicide for black mold based on weather forecast. In the case of a late harvest, apply kaolin clay for sunburn prevention if feasible (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Harvest: Harvest in a timely manner (if possible) to prevent development of fruit rots.

For more information on identification, monitoring, and management of this disease, see:
ipm.ucanr.edu/agriculture/tomato/Black-mold
ipm.ucanr.edu/agriculture/tomato/Water-Mold-Fruit-Rot
ipm.ucanr.edu/agriculture/tomato/Gray-Mold

## Late Blight

Late blight (*Phytophthora infestans*) is an occasional problem in all growing regions. It can develop any time from planting to late fruit set. Leaves develop purple-to-brown blotches and later die. Infected fruit are discolored.

Current management practices are generally effective against this disease. These include fungicides, delaying irrigation (especially through sprinklers, if applicable) if wet weather conditions persist, monitoring nearby potato crops for this disease, and removing solanaceous weeds from the field.

Fungicides used for late blight include chlorothalonil (Bravo) and the premix of famoxodone and cymoxanil (Tanos).

Summary of stage-specific management practices:

- Planting to Prebloom, Bloom to Early Fruit Set, Late Fruit Set: Delay irrigation in wet conditions, monitor nearby potato fields, remove solanaceous weeds, and apply fungicide if disease develops (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Late-Blight.

## Powdery Mildew

Powdery mildew (*Leveillula taurica*) is one of the most damaging late-season diseases of processing tomato statewide and can cause damage any time from bloom to harvest. It severely defoliates the crop, increases sunburn of the fruit, and in turn increases infection by black mold and other fruit rots. In northern growing regions, entire fields can be damaged by powdery mildew if it is not properly managed.

Cultural methods used for powdery mildew include avoiding sprinkler irrigation (if applicable) and trimming vines to increase air circulation. Various fungicides may be applied to prevent powdery mildew development (see Efficacy Tables and *Pest Management Guidelines: Tomato*). The disease is very difficult to control once it becomes established in the crop.

A forecasting model was developed more than a decade ago to assist with fungicide application timing for powdery mildew. However, because the model does not accurately predict powdery mildew severity and proper application timing, it is no longer used.

Summary of stage-specific management practices:

- Bloom to Early Fruit Set: Avoid sprinkler irrigation (if applicable). Apply fungicide in conditions that favor powdery mildew development (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*). Monitor for powdery mildew.
- Late Fruit Set: Avoid sprinkler irrigation (if applicable) and trim vines to increase air circulation. Apply fungicide in conditions that favor powdery mildew development (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*). Monitor for powdery mildew.
- First Red Fruit: Avoid sprinkler irrigation (if applicable). Apply fungicide if conditions favor powdery mildew development if possible (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*). Monitor for powdery mildew.

For more information on identification, monitoring, and management of this disease, see: ipm.ucanr.edu/agriculture/tomato/Powdery-Mildew-on-Field-Grown-Tomatoes.

## Southern blight

In recent years, southern blight (*Sclerotium rolfsii*) has become a major problem in processing tomato throughout the state, which is speculated to be due to the widespread adoption of subsurface drip irrigation. Greater issues with southern blight may also be facilitated by increasingly warm temperatures during the growing season, as this disease develops at temperatures greater than 86°F.

This disease causes lesions to develop on stems at the soil line, girdling the plant and causing it to wilt. In the southern growing regions, southern blight can render entire fields unusable for processing tomato. It can appear in the field as early as bloom, through fruit set and ripening.

In the northern growing regions, southern blight infection appears to be exacerbated by salt buildup. Drip irrigation deposits salt beneath the soil surface, which creates a barrier that holds moisture and favors the development of the disease. The process of leaching salts or otherwise breaking up salt buildup may be an important preventive practice for this reason. Southern blight may also be more common in heavy soils and fields with a history of growing rice or tomato.

Crop rotation and deep plowing that inverts the soil have been suggested to be useful practices in *Pest Management Guidelines: Tomato*. However, deep plowing is no longer used since subsurface drip irrigation has been adopted, and crop rotation may not be effective because of the pathogen's extensive host range.

Planting early is believed to be an effective management practice in the southern growing region. However, adjusting the timing of planting is not always possible due to contracts with processors.

Fungicides are generally not effective for this disease. Preplant fumigation with metam sodium (Vapam) provides some control but does not eliminate the pathogen.

Summary of stage-specific management practices:

- Preplant: Consider fumigation with metam sodium if southern blight has been a problem (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Planting through Harvest: Plant early (if possible) and keep beds dry.

For more information on identification, monitoring, and management of this disease, see: [ipm.ucanr.edu/agriculture/tomato/Southern-Blight](ipm.ucanr.edu/agriculture/tomato/Southern-Blight).

## Verticillium wilt

Verticillium wilt (*Verticillium dahliae*) is an early-season disease of processing tomato primarily in the northern growing regions. It does not kill tomato plants but reduces yields by damaging and killing the foliage, which increases sunburn damage and infection by fruit rots.

Current nonchemical management practices primarily consist of sanitation (e.g., cleaning field equipment). Resistant varieties were previously used to manage Verticillium wilt race 1, but this strain of the disease is no longer a major problem. Verticillium wilt race 2, for which there are no resistant varieties, is more prevalent.

The only current pesticide option for Verticillium wilt is preplant fumigation with metam sodium (Vapam) or metam potassium (K-Pam). Otherwise, fungicides are not used for this disease.

Summary of stage-specific management practices:

- Preplant: Fumigate with metam sodium or metam potassium if Verticillium has been a problem in the field (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Planting to Prebloom, Bloom to Early Fruit Set: Use good sanitation to prevent bringing inoculum into noninfested fields.

For more information on identification, monitoring, and management of this disease, see: [ipm.ucanr.edu/agriculture/tomato/Verticillium-Wilt](ipm.ucanr.edu/agriculture/tomato/Verticillium-Wilt).

## Nematodes

Root-knot nematodes (*Meloidogyne* spp.) are the only type of nematode that damage processing tomato at this time. Damage from these pests is occasional but has been increasing. It can occur anytime between planting and late fruit set (damage is less common once fruit begins to ripen). Nematodes also remain a concern because they increase the risk of Fusarium wilt infection. Damage from nematodes tends to decrease once fruit begins to ripen.

Resistant varieties are commonly used to prevent damage from these pests. However, root-knot nematodes (especially *Meloidogyne javanica* and *Meloidogyne incognita*) are more often overcoming host resistance, often under higher temperatures (more common in the southern region than in the northern region). Nematode management requires sampling soil for nematodes before planting. In the southern growing regions, management also may entail rotating to wheat in some situations and avoiding planting in sandy soils.

Fumigants such as metam or 1,3-dichloropropene (Telone) may be used preplant if nematode numbers are high, but newer nematicides such as fluensulfone (Nimitz) are preferred because of their reduced risks to workers. Nimitz is very effective but can only be applied once before planting. Fluopyram (Velum One) or oxamyl (Vydate) can be used during the season if nematodes are an issue. Oxamyl can be used to manage nematodes early in the season, while fluopyram can be applied later if necessary (though it tends to be more effective when applied early). However, fluopyram can only be applied at the full label rate twice per season, which can be restrictive since this is also an important fungicide for powdery mildew management. Its effectiveness can also vary from year to year.

Summary of stage-specific management practices:

- Preplant: Sample soil for nematodes, choose resistant varieties, avoid planting in sandy soils (in the southern region), and apply nematicide or fumigate soil if necessary (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Planting to Prebloom, Bloom to Early Fruit Set, Late Fruit Set: Apply in-season nematicide if nematodes are damaging the crop (see above text, Efficacy Tables, and *Pest Management Guidelines: Tomato*).
- Postharvest: Rotate to wheat (in the southern region).

For more information on identification, monitoring, and management of nematodes, see: ipm.ucanr.edu/agriculture/tomato/Root-knot-nematodes.

## Weeds

Weed problems differ somewhat between the northern and southern growing regions. However, there are several difficult-to-control weeds that pose a problem in processing tomato throughout the state. Field bindweed and broomrape are currently the weeds that pose the greatest statewide concern. Other weeds, such as hairy fleabane, nightshades, and yellow nutsedge are also major issues. Below is a list of the weed concerns in processing tomato, the regions where they are a problem, and the methods used to manage them. For a more detailed description of general weed management practices at each stage of the growing season, see Farming and IPM Activities, Efficacy Tables, and *Pest Management Guidelines: Tomato*.

### Alkali mallow

Alkali mallow (*Malvella leprosa*) is native to California and is increasingly infesting processing tomato fields in the southern growing regions. It is a perennial weed with an extensive root system and spreads easily by both seed and vegetative fragments.

Control requires repeated cultivation. Because alkali mallow is a newer weed problem, the efficacy of currently available herbicides against this weed in processing tomato is currently unknown. Systemic herbicides may provide some control.

### Alkaliweed

Alkaliweed (*Cressa truxillensis*), or alkali clover, has become a problem particularly in the southern San Joaquin Valley. This is a perennial weed that is native to California and closely related to field bindweed. Alkaliweed spreads by both seed and belowground rhizomes. It may be becoming more of an issue due to its ability to tolerate saline and alkali conditions. The use of drip irrigation likely favors its spread.

### Broomrape

There are two species of broomrape that have been detected in California processing tomato fields: branched broomrape (*Orobanche ramosa*) and Egyptian broomrape (*Orobanche aegyptiaca*). These weeds are parasitic and derive their nutrients directly from the crop. Broomrape becomes noticeable only as it begins to flower, which occurs from bloom (full bloom) through harvest. Prior to this stage, their development takes place mostly underground. Even when these weeds emerge from the ground, they are difficult to detect because it is often hidden by the crop canopy.

Both species are Class A pests in California—detection typically leads to destruction of the entire crop (by herbicide application) and can take a field out of production for several years (only alternate rotational crops approved by the Agricultural Commissioner may be grown, harvested and sold after a detection). Egyptian broomrape was first detected in California in 2014. Branched broomrape was first detected in 1929. Broomrape detections must be reported to the local county agricultural commissioner and the California Department of Food and Agriculture.

Both broomrapes produce copious amounts of tiny seed (see *Weeds and Other Unwanted Plants: Egyptian Broomrape*), which can easily be spread by field machinery (especially harvest equipment). This seed can persist in the soil for as long as 25 years. Seed can be released by the plant before it is removed from the field, enabling future infestations even if mature plants are removed before harvest. Harvester movement is considered to play a critical role in the spread of broomrape. During harvest, harvest equipment can move through several counties in a short time span, potentially turning patchy and isolated infestations into widespread problems.

Broomrape is the biggest threat to the processing tomato industry in the northern growing regions but is also a major concern in the southern growing regions. There is widespread agreement that everyone in the processing tomato industry must take the threat seriously in order for it to be adequately addressed. Broomrape is a serious concern to the extent that increasing regulations may be needed to prevent further spread and crop loss.

**Dodder**

Dodder (*Cuscuta* spp.) is a parasitic weed that is more commonly a problem in the northern region, from soon after planting until harvest. It is very difficult to control without damaging the crop.

The most common management practice is to avoid planting processing tomato in dodder-infested soils. Dodder-tolerant processing tomato cultivars have also been used as a management strategy in the past. These cultivars have been highly effective at reducing dodder attachment and seed production. However, the market for these cultivars is small, and no new cultivars have been developed in recent years.

Preplant fumigation with metam sodium (Vapam) or potassium (K-Pam) can provide some control in fields where dodder has been a problem. In-season application of rimsulfuron (Matrix) can also provide some control of dodder.

Persistently hand-rogueing (by removing plants with attached dodder at earliest detection) and managing dodder before it is able to produce seed can eventually reduce the infestation. Rotation with monocots (such as rice or wheat) can slowly reduce the seed bank, since these are not hosts of dodder. Planting on a late schedule after peak dodder germination can reduce infestation, though this is not always possible due to contracts with processors.

**Field bindweed**

Field bindweed (*Convolvulus arvensis*) is one of the top weed problems in processing tomato statewide and can be a problem any time from planting through the fallow period. This weed has very limited control options. It was previously managed by deep tillage that fully inverted the soil, but this practice is no longer used to avoid destroying buried drip tape.

While hand-weeding or hand-hoeing is highly effective against most weeds (especially early in the season), it does not effectively eliminate field bindweed. Herbicide applications do not provide complete control of bindweed, though some can suppress its growth (see Efficacy Tables).

Glyphosate (Roundup) is used to manage bindweed, but applications of this herbicide are often only partially effective, especially in the northern region. Glyphosate must be applied while it is actively growing in the spring, or when bindweed is in bloom in order to suppress its growth. It is much less effective on moisture-stressed bindweed, as well as bindweed that has dust on its leaves. Glyphosate also only controls the aboveground growth of field bindweed and does not eliminate underground structures such as rhizomes.

Trifluralin (Treflan) suppresses the growth of bindweed seedlings but does not eliminate the weed.

**Groundcherries (tomatillo)**

Groundcherries (*Physalis* spp.) are typically late-season weeds in the northern region. They are closely related to tomato and are difficult to control with herbicides without damaging the crop. Groundcherries also host several diseases of tomato (bacterial speck, late blight, etc.) and can facilitate infection of the crop.

Broad-spectrum herbicides used on fall fallow beds and herbicides applied after planting (especially rimsulfuron and metribuzin) can help reduce groundcherries to some extent. Because these weeds germinate in the top 2 inches of soil, mechanical cultivation is an important component of control in the early part of the season. Removal of groundcherries late in the season may require extensive hand-weeding, which is costly.

**Hairy fleabane**

Hairy fleabane (*Erigeron bonariensis*, formerly *Conyza bonariensis*) is both a preplant and late-season problem in processing tomato throughout the state, largely due to glyphosate resistance. In the northern growing region, few management options work against this weed. Cultivation will kill fleabane seedlings and is usually necessary after planting until the crop is too large. Metribuzin provides only partial control.

Managing fleabane especially around the perimeter of the field helps to prevent the encroachment of this weed into the crop.

**Horseweed**

Horseweed (*Erigeron canadensis*, formerly *Conyza canadensis* and also known as mare’s tail), is a regular problem in the northern growing regions and is becoming a greater issue in the southern growing regions. It is closely related to hairy fleabane. Horseweed can be an issue from planting to harvest. It easily reinvades areas where it was previously controlled due to its highly mobile seeds. Similar to hairy fleabane, managing horseweed around the perimeter of the field is an important practice for preventing infestations within the field.

Cultivation helps reduce this weed when it is small and is important to managing herbicide-resistant populations. Cultivation is also an important aspect of preventing further development of herbicide resistance.

Herbicides that control horseweed are applied during the fallow and preplant periods. Paraquat (Gramoxone) applied to fall fallow beds can control horseweed, but glyphosate-resistant horseweed is also occasionally resistant to paraquat. Flumioxazin (Chateau) is usually effective against horseweed. Fumigation with metam sodium or metam potassium (Vapam or K-Pam) can be effective.

**Italian ryegrass**

Italian ryegrass (*Lolium multiflorum*) has become resistant to glyphosate and other herbicides in some regions of California and is becoming a greater problem in the northern region.

Glufosinate (Rely) has been found to control Italian ryegrass in other crop systems, but in processing tomato this herbicide can only be used during the fallow period (at least 180 days before planting), when Italian ryegrass has already senesced. Trifluralin (Treflan) applied before planting can also provide some preemergence ryegrass control, as well as sethoxydim (Poast) or clethodim (Select Max) applied during the season. Cultivation is also very important for managing this weed.

Managing ryegrass around the perimeter of the field helps to prevent the encroachment of this weed into the crop.

**Johnsongrass**

Johnsongrass (*Sorghum halepense*) is problematic in the northern growing regions, especially early in the season, when tomatoes are small and less able to compete with weeds. It may become a greater problem later in the season if it is not managed well during the early stages of growth. Johnsongrass is a perennial grass that spreads through both rhizomes and seeds. It can grow to be up to 7 feet tall.

Preemergence herbicides that are used in processing tomato only control seedlings of Johnsongrass, not established plants emerging from belowground rhizomes. Repeated application of postemergence herbicides such as glyphosate (Roundup) and sethoxydim (Poast) are usually necessary to reduce Johnsongrass over several seasons. Glyphosate tends to be most effective when Johnsongrass is between 1 to 2 feet tall and actively growing. Sethoxydim (Poast) and clethodim (Select Max) are also selective to grasses and can be used during the season (though typically only used as rescue treatments) without harming the crop. However, clethodim only partially controls Johnsongrass.

**Lambsquarters**

Lambsquarters (*Chenopodium album*) is an annual weed that can be a problem especially in processing tomato in the southern growing region throughout the season. It is also a host of beet leafhopper and can facilitate infection with *Beet curly top virus*.

Cultivation can be used to manage lambsquarters prior to planting and early in the season when it is in the seedling stage. Hand-weeding is used to manage lambsquarters late in the season.

Preplant herbicide applications can help to manage lambsquarters. Rimsulfuron (Matrix) can be used to manage lambsquarters during the season.

**Little mallow**

Little mallow (*Malva parviflora*) is an annual weed that can also be biennial or perennial. It is an issue in both the northern and southern growing regions. This weed can grow to be fairly large (often 2 to 3 feet tall, sometimes as tall as 5 feet), and if it is not managed well, its presence in fields can interfere with harvest equipment. The mature stage of little mallow has a strong taproot that makes it challenging to eliminate with either herbicides or mechanical methods. Additionally, little mallow attracts stink bugs, thrips, and whiteflies and is also a host of *Tomato spotted wilt virus*.

Little mallow can be managed with flumioxazin (Chateau), oxyfluorfen (Goal), or glyphosate. Glyphosate helps control emerged mallow seedlings only. It is ineffective at controlling mature stages of little mallow.

Little mallow that is present in fields during the season can be controlled with cultivation during the early part of the season. Hand-weeding may also be necessary to remove little mallow from the field. Managing little mallow around the perimeter of the field is also an important practice for avoiding infestations within the field.

**Nettleleaf goosefoot**

Nettleleaf goosefoot (*Chenopodium murale*) is an annual weed that can be present in the crop throughout the season. It is a problem in both the northern and southern growing regions. It poses a problem particularly because it is attractive to beet leafhopper and can facilitate infection of the crop with *Beet curly top virus*.

Early-season cultivation and various herbicides control this weed (see Efficacy Tables and *Pest Management Guidelines: Tomato*). Hand weeding can also be important to nettleleaf goosefoot management.

**Nightshades**

Similar to groundcherries, black nightshade (*Solanum nigrum*) and hairy nightshade (*Solanum sarrachoides*) are closely related to tomato and are difficult to completely control with herbicides without damaging the crop. They also host several diseases of tomato (e.g., bacterial speck and late blight) and can facilitate infection of the crop. These weeds are a major issue in processing tomato throughout the state.

Nightshades may be present throughout the season. They compete with the crop seedlings early in the season, and at later stages (late fruit set until harvest) they require hand-weeding to prevent increases in seed. Late-season hand weeding for nightshades and other weeds can be costly. At earlier crop stages, nightshades are more easily managed with mechanical cultivation.

Because nightshades are closely related to tomato, these weeds are difficult to manage with herbicides during the season without damaging the crop. Broad-spectrum herbicides applied during the fallow period controls emerged nightshades, as well as glyphosate applied preplant. S-metolachlor (Dual Magnum) applied preplant also helps manage nightshades before they emerge. Preplant and postplant application of rimsulfuron (Matrix) is effective at managing nightshades before their emergence or soon after. Metribuzin can also control nightshades but is more effective against hairy nightshade than it is against black nightshade.

**Perennial pepperweed**

Perennial pepperweed (*Lepidium latifolium*) is a troublesome perennial weed in the southern growing region. Once established, it is very hard to control. This weed also is attractive to beet leafhopper and can facilitate infection with *Beet curly top virus*.

This weed is very difficult to manage with herbicides; a single application rarely eradicates it from a field. Preemergence herbicides are less effective against this weed because it primarily spreads through roots rather than seed. The main herbicide available for managing perennial pepperweed in processing tomato is glyphosate.

Cultivation is very important to management of this weed because it disturbs the root system, but it does not provide sufficient control of established plants. Hand-weeding is necessary to reduce infestations, but this practice can be overwhelming on land that is severely infested.

**Russian thistle**

Russian thistle (*Salsola* spp.) is an annual weed that can be a problem in both the northern and southern growing regions. In the southern region, it attracts beet leafhopper and facilitates transmission of *Beet curly top virus*. It is also a food source for developing stink bugs statewide and facilitates stink bug migration into the crop.

Few herbicides control this weed, and it is especially difficult to control once it reaches maturity. Trifluralin (Treflan) helps control Russian thistle before it emerges. Glyphosate helps to reduce emerged Russian thistle seedlings before planting. Metribuzin provides some suppression of Russian thistle if it is applied when the weed is small or before it emerges.

**Sowthistles**

Both annual and perennial sowthistles (*Sonchus* spp.) are a concern to growers in the southern regions due to their role in facilitating the spread of *Tomato spotted wilt virus*. Various herbicides control annual sowthistle (see Efficacy Tables and *Pest Management Guidelines: Tomato*), but perennial sowthistle is much more difficult to manage with herbicides. These weeds can be a problem year-round.

**<u>Sunflowers</u>**

Volunteer and glyphosate-resistant sunflowers (*Helianthus* spp.) can be a problem throughout the growing season (preplant through early fruit set in particular) in the northern growing regions. In this area, Roundup-ready sunflowers are used in crop rotations. These become bigger weed problems in subsequent rotations with processing tomato because they are not affected by fallow bed or preplant applications of glyphosate.

Preplant and early-season cultivation reduce emerged sunflower seedlings and is especially important for managing glyphosate-resistant sunflowers. Applications of metribuzin or halosulfuron also help manage sunflowers (see Efficacy Tables). Hand weeding is also often necessary to manage these weeds.

**<u>Velvetleaf</u>**

Velvetleaf (*Abutilon theophrasti*) is a late-season weed in the northern growing regions. Hand-weeding is used to manage this weed, as well as applications of metribuzin and halosulfuron (Sandea). Preplant or fallow bed herbicide applications (especially fallow bed application of carfentrazone, or Shark) are necessary in addition to in-season control.

**<u>Yellow nutsedge</u>**

Yellow nutsedge (*Cyperus esculentus*) is a perennial weed that poses a persistent problem in processing tomato throughout the state. Though yellow nutsedge can be present in process tomato throughout the season, infestations are most serious early in the season, when the crop is small and soil moisture is high from precipitation. One of the major management methods to reduce nutsedge was to deep plow to bury belowground rhizomes deep enough (at least 12 inches) to prevent further germination. Since the adoption of buried drip irrigation, yellow nutsedge has become more difficult to control. Herbicides that are currently used to control yellow nutsedge include s-metolachlor (Dual Magnum) applied preplant before yellow nutsedge emerges. Halosulfuron (Sandea) may be applied to emerged nutsedge foliage during the layby period as well.

## Vertebrates

Vertebrates can cause serious damage to processing tomato both directly and indirectly. Direct damage includes feeding on fruit, foliage, or roots. Indirect damage includes crop contamination from feces and damage to the drip tape. Many vertebrate pests of processing tomato chew through drip tape, causing some plants to be overwatered and prone to fungal diseases and leaving others water-stressed. There is a great need for IPM practices that include drip tape maintenance and protection, because current methods are inadequate and costly.

### Birds

Ravens (*Corvus corax*) and crows (*Corvus brachyrhynchos*) damage processing tomato in the southern region. They feed on the crop and can increase risk of crop contamination by defecating in the field. Bird guns (noise-making scare devices) and electronic distress calls are effective against some bird pests, as well as removing habitat where these birds can potentially nest.

Summary of stage-specific management practices:

- Preplant: Remove habitat where birds can nest.
- First Red Fruit through Harvest: Use bird guns to discourage birds from feeding on the crop.
- Postharvest: Remove habitat where birds can nest.

### Burrowing rodents

Burrowing rodents are currently the greatest vertebrate pest problem in processing tomato throughout the state and can damage the crop throughout the growing season. These pests include gophers (*Thomomys* spp.), ground squirrels (*Otospermophilus* spp.), and voles (*Microtus* spp.).

Burrowing rodents generally feed on plants and chew drip tape. In addition to this damage, gophers may pull entire tomato plants into their underground burrows. Voles can also get caught in harvesting equipment, which poses a risk of food contamination.

Effective methods that were previously used to manage these pests, such as flood irrigation and running butyric acid through the drip tape, are now either unavailable or extremely limited.

Current practices mostly combine trapping, habitat modification or elimination, and monitoring. Eliminating weeds and other vegetation around the field that provide habitat and food for burrowing rodents is a major part of their management. Removal of this habitat also makes it easier to monitor and identify burrow entrances and mounds. Processing tomato fields near orchards with owl boxes are generally experienced to have fewer rodent problems, especially damage from gophers and voles. Fields that are visited by coyotes also generally experience less rodent damage, though such differences have not been scientifically verified and quantified.

Use of rodenticide baits and burrow fumigation are much less common in processing tomato. All rodenticides are restricted-use pesticides for agricultural field applications, and few rodenticides are explicitly registered for use in processing tomato. Rodenticide baits that may be used to manage any of these species in agriculture include the first-generation anticoagulants chlorophacinone, diphacinone, and warfarin, as well as the acute toxicant zinc phosphide. Strychnine can be used for pocket gophers, but not for ground squirrels or voles. Second-generation anticoagulants such as bromadiolone and brodifacoum and some other rodenticides (e.g., bromethalin) are never available for field use for any of these species. Some baits can only be used within a certain distance (usually 50 or 100 feet) of a building or structure. Baits also degrade over time and need to be replaced in order to maintain their efficacy. This can be a barrier to successful rodent management with baits.

Baits are more available to use in the field during the winter or early spring, before tomatoes are planted. However, applying baits during this time is less effective for pests such as ground squirrels, which become inactive (via either estivation or hibernation) when food is less available and temperatures are extreme. During the season, some baits can be used in vegetable crops such as processing tomato if applied in bait stations around the perimeter of the field (for voles and ground squirrels), or directly in the burrows (for gophers).

Burrow fumigation is effective for some species but is rarely used in processing tomato. Effectiveness varies depending on the fumigant and target species. Potential burrow fumigants include aluminum phosphide, gas cartridges, and carbon monoxide and carbon dioxide injection devices. Aluminum phosphide is also a restricted-use pesticide and poses risks to worker safety and nontarget organisms.

There are growing concerns about rodenticide baits and fumigants due to their risk to predators and other nontarget species. The availability of rodent control measures (including trapping as well as rodenticides) can also be limited by endangered species that are present in the area. In several major processing tomato growing counties (including Fresno, Kings, Kern, Merced, San Joaquin, and Stanislaus), the need to protect species such as the San Joaquin kit fox and several kangaroo rat species means that rodent management strategies must meet additional requirements or otherwise must be restricted.

There is some variation in effectiveness and timing of burrowing rodent management methods depending on the species (see Efficacy Tables and text below).

*<u>Gophers</u>*

Gophers are easiest to control from late fall through early spring. Traps are highly effective against gophers and can be used throughout the year.

Though rarely used (see above text under Burrowing Rodents), fumigation can be used to kill gophers in late winter or early spring, when the soil is moist. Strychnine is generally the most effective bait available for gopher control. Baits are more available to use for gophers during the growing season than they are for the other burrowing rodents, since several rodenticides are allowed to be applied directly in gopher burrows in vegetable crops.

Odorant repellents (rotten egg scent) have been experimented with for gopher management but have been observed to be ineffective. A new repellent (active ingredient methyl mercaptan) has recently also been registered for gophers for use in subsurface drip irrigation. However, the efficacy of this product is not known and efficacy trials are underway.

Deep tillage also helps to destroy gopher burrows but is seldom used due to the need to preserve drip tape.

Summary of stage-specific management practices:

- Preplant: Remove vegetation that provides habitat or food for gophers, trap gophers. If necessary, consider burrow fumigation or apply baits if possible (see above text).
- Planting to Prebloom, Bloom to Early Fruit Set, Late Fruit Set: Remove weeds and other vegetation that provide habitat and food for gophers. Continue to trap gophers as necessary and apply baits in gopher burrows if allowed (see above text under Burrowing Rodents).
- Postharvest: Use deep tillage to destroy burrows if possible. Otherwise, continue to trap gophers and remove vegetation that provides gopher habitat.

*Ground squirrels*

Deep plowing can help manage ground squirrel populations and destroy burrowing systems, but due to widespread use of subsurface drip irrigation, this practice is seldom used. Trapping can be used to manage ground squirrels but is usually only practical when their numbers are low. Shooting can be used to reduce ground squirrels when their numbers are low, but this is generally not practical.

Burrow fumigation in late winter or early spring (2 to 3 weeks after ground squirrels emerge from their burrows) can help to reduce ground squirrel infestations before planting. However, burrow fumigation is seldom used in processing tomato (see above text under Burrowing Rodents).

Rodenticide baits are crucial to ground squirrel management in agriculture. Because of the squirrels' seasonal feeding habits, grain baits are generally most effective against ground squirrels in the late spring through early summer. However, because few bait products are explicitly registered for use in processing tomato, most bait applications are done before the tomatoes are planted, which is much less effective for this pest. Depending on the product, some baits may be available to use in bait stations around the perimeter of fields.

In the late spring and summer especially, it can be especially important to focus trapping and baits (if used) around the perimeter of the field to prevent ground squirrels from entering the field from surrounding areas.

Summary of stage-specific management practices:

- Preplant: Remove vegetation that provides habitat for ground squirrels, trap ground squirrels if their numbers are low. Consider burrow fumigation if necessary (see above text under Burrowing Rodents).

- Bloom to Early Fruit Set, Late Fruit Set: Remove vegetation that provides habitat for ground squirrels. If possible, apply rodenticide baits around the perimeter of the field to prevent ground squirrels from moving into the crop (see above text under Burrowing Rodents). Trap ground squirrels around the perimeter of the field.
- First Red Fruit through Harvest: Trap or apply baits (if possible) around the perimeter of the field (see above text).
- Postharvest: If possible, use deep tillage to destroy ground squirrel burrows. Control weeds and other vegetation that provides ground squirrel habitat.

*Voles*

Rodenticide baits are the best management method available for voles at this time; however, in processing tomato there are fewer rodenticides available for voles than there are for ground squirrels and gophers. Fumigation with aluminum phosphide is generally ineffective for voles because their burrows are too shallow and open. Trapping is typically used for detection only, since voles are usually too numerous to manage with traps. The practice of discing or otherwise cultivating fields after harvest and before planting destroys vole burrows and helps reduce overwintering success.

Summary of stage-specific management practices:

- Preplant: Cultivate fields to destroy vole burrows. Trap voles to detect their presence in the field. Apply baits around the perimeter of the field if possible (see above text).
- Planting through First Red Fruit: Trap voles to detect their presence. Apply baits around the perimeter of the field if possible (see above text).

## Coyotes

In the southern region, coyotes (*Canis latrans*) are considered both pests and beneficial predators. The presence of coyotes reduces rodent pests, and therefore controlling coyotes can increase rodent populations. However, coyotes may also chew drip tape to access water, and drip tape damage is intolerable. Shooting is the only method available for coyote management but tends not to be used unless coyotes are observed damaging the drip tape.

## Deer

Deer (*Odocoileus hemionus*) are an occasional issue in the northern growing region. Deer eat the tomato fruit from the first red fruit stage up to harvest and can cause more damage than rabbits or ground squirrels in some situations. Tall fencing is the main option available to protect the crop from deer feeding, but fencing is not often used due to the labor intensiveness and cost ineffectiveness of fencing large areas of land.

Summary of stage-specific management practices:

- Planting to Prebloom: Place tall fencing around the field to prevent deer from entering, if deer are a problem in the area and if financially feasible.

## **Rabbits**

Rabbits (*Lepus californicus*, *Sylvilagus* spp.) are primarily a problem for stakeholders in the southern growing region. Rabbits feed on the crop and can occasionally chew drip tape. Fencing prevents damage from rabbits but is not often used (see Deer). Processing tomato fields that are visited by coyotes tend to experience less rabbit damage. Odorant repellents (rotten egg scent) have not been found to prevent rabbit damage. Shooting can be effective against low numbers of rabbits but is generally not practical.

Summary of stage-specific management practices:

- Planting to Prebloom: Place fencing around the field to prevent rabbits from entering, if rabbits are a problem in the area and if fencing is financially feasible.

# Pests of Future Concern

## Brown marmorated stink bug

Brown marmorated stink bug (*Halyomorpha halys*) is an invasive stink bug that is native to east Asia and has been present in California since 2005. Although it has not yet caused damage to processing tomato, its presence in residential areas and its high mobility make it a serious concern. Brown marmorated stink bug feeding causes damage that is very similar to other stink bugs. Considering the difficulty of managing current stink bug problems in processing tomato, the invasive nature of brown marmorated stink bug would create an even more challenging stink bug situation for this crop.

## *Tomato brown rugose fruit virus*

*Tomato brown rugose fruit virus* is not currently established in California. The California Department of Food and Agriculture has classified this virus as a Class A pest and rated its potential to spread in California as high. It has also been spreading in other parts of the world, including China, Mexico, Jordan, Turkey, Italy, Greece, and the United Kingdom. Though it is more of a problem in tomatoes grown in protected environments like greenhouses, some outbreaks have occurred in tomato fields in Mexico.

The virus causes mottling and mosaic patterns on leaves, discoloration and deformation of the fruit, and stunted tomato plants. Tomato varieties that are resistant to many other viruses remain susceptible to tomato brown rugose. At this time not much is known about its overall impacts and management. The virus spreads via mechanical means, including movement of soil, seeds and other plant material. It persists for many years in both soil and plant material. It is not associated with an insect vector.

## South American tomato leafminer

South American tomato leafminer (*Tuta absoluta*) has not yet been found in California. It is native to the Andes region of South America but has spread to Europe, North Africa, Asia, and southern Central America over the past several years. Projections from computer models suggest that this pest will eventually make its way to California.

South American tomato leafminer is highly destructive to tomato, causing crop losses of 80 to 100% in areas where it is found. It bores into various parts of the plant, alters the growth pattern of the crop, and renders the fruit unmarketable. It can also infest other solanaceous plants. For more information, see *Exotic and Invasive Pests: South American Tomato Leafminer*.

# FARMING AND IPM PRACTICES

This section describes the agricultural practices that occur in processing tomato at each of the major stages throughout the season, as well as the major pests that are managed (or otherwise damaging) at each stage. Details on specific management practices for insects, pathogens, nematodes, and vertebrate pests can be found in the Foundation for a Pest Management Strategic Plan section. Efficacy information for available and commonly used management practices can be found in the Efficacy Tables.

Because weeds are managed more collectively than individually, general weed management practices and herbicides that may be used at each stage are described in this section. These details are also available in this section to provide further context for herbicide timing than is currently provided in the Herbicide Efficacy Tables.

## Fallow and Preplant

The fallow period for California processing tomatoes typically extends from fall through the middle of winter, and the preplant period includes late winter and early spring. (The fallow period may also be considered postharvest.) The major farming activities that take place during these periods include selecting the field and the varieties to plant, forming the beds and furrows, sampling soil for nutrients and pests, conducting weed management activities, managing invertebrate and vertebrate pests, and applying fertilizer. Beds may be fumigated during either the fallow or preplant period if necessary. The irrigation system may be maintained or replaced during fallow. Many preventive practices, such as cultivating soil and allowing organic matter to decompose, are also used during this time to reduce damage from early-season pests such as wireworms and symphylans. However, processing tomatoes that utilize no-till practices or conservation tillage may allow undecomposed organic matter to remain in the field through planting, and may experience little or no damage from these pests.

During the time the field is prepared for planting, processing tomato transplants are planted and grown in greenhouses.

### Field and Variety Selection

Field and variety selection depends heavily on the pest problems that occurred in the previous crop, especially if the previous crop was tomato. The presence of severely damaging pests such as Fusarium wilt, southern blight, or quarantined pests such as broomrape render fields unusable for processing tomatoes. For some pests, including dodder, root-knot nematodes, and various diseases (e.g., Fusarium wilt), resistant or tolerant varieties can be chosen if such pests have been a problem in the field. Fields may also be selected based on what crops are grown nearby, as this can also influence pest infestations and damage.

### Irrigation Maintenance or Replacement

The vast majority of California processing tomatoes are irrigated using subsurface drip systems, while a smaller number of operations use traditional furrow irrigation and sprinklers. Drip irrigation has benefited the industry by reducing weed competition, increasing water efficiency, and increasing yields. Drip tape is buried 8 to 12 inches below the surface of the beds. Only 10% of the crop was drip-irrigated in 1990; this later rose to 20% in 2008, and 78% in 2012. More than 90% of California processing tomatoes now utilize subsurface drip irrigation.

In drip-irrigated processing tomato fields, the fallow period is the best time to remove and replace old, damaged drip tape if necessary (typically once every 5 years) and break up any salt buildup (which is usually more problematic in the southern growing regions) near the drip line to increase drainage.

## Bed Formation and Listing

The preparation and maintenance of raised beds and furrows are important for weed control, harvest, and other farming activities. Beds are typically formed in the fall and left fallow until planting in the spring; however, in some cases (e.g., fields under conservation tillage or no tillage) they may be planted with winter cover crops (see Harvest and Postharvest). Fields are first disked and leveled, and machinery such as land planes and bed listers are used to form the beds. Beds are typically 60, 66 or 80 inches wide (measured from the center of one adjacent furrow to the other). In furrow-irrigated processing tomatoes, fields are graded before planting, and furrows should be maintained during the season.

## Cover Crop Management

In fields that are planted with fall and winter cover crops (i.e., fields under no tillage or conservation tillage), the cover crop is killed with a burndown herbicide such as glyphosate before planting, typically in late February or early March. Strip tillage is then used to incorporate herbicide and cover crop residue into the soil, as well as loosen the soil of the transplant line to prepare for planting.

## Weed Management

### *Fallow*

The fall fallow period is a critical period for weed management. Depending on the weather conditions, cultivation equipment may be used to eliminate emerged weeds. Cultivation during this time helps to kill emerged weeds, break up compacted soil in the furrows, and incorporate weed and crop residues into the soil. The bed tops and shoulders are shallowly cultivated, and the furrow bottoms are often tilled to a depth of 8 to 10 inches using chisel shanks. Deep tillage of the furrow bottoms using chisel shanks does not risk damage to the drip tape.

Various burndown herbicides are also used on emerged weeds during this time (see Efficacy Tables for more information). Flumioxazin (Chateau) may also be used as a preemergence treatment at this time. Herbicides used during the fallow period generally have longer plantback restrictions (especially glufosinate, which cannot be applied less than 180 days from the transplanting date for processing tomato). The exceptions are glyphosate (Roundup PowerMax) and carfentrazone (Shark), which may be used during the fallow period but are often applied closer to planting (see Efficacy Tables for more information).

*Preplant*

Because late winter is often dominated by rainy and wet conditions (especially in the northern region), growers may not be able to conduct preplant weed management activities in fields until wet conditions subside, to avoid soil compaction from heavy machinery. If there is a break in rainy weather, cultivation equipment may be used to reduce weeds throughout the field. Glyphosate (Roundup PowerMax) may also be applied using lightweight all-terrain vehicles to avoid compacting soil with heavier machinery. It is common for glyphosate to be applied to emerged weeds before planting.

Herbicides that may be applied before planting and before weeds emerge include trifluralin (Treflan HFP), s-metolachlor (Dual Magnum), and pendimethalin (Prowl H2O). Preplant herbicides that control weeds both before and shortly after they emerge include oxyfluorfen (Goal or GoalTender) and metribuzin (Metribuzin 75). Preplant herbicides that control only emerged weeds (burndown treatment) include glyphosate and carfentrazone (Shark EW). Sulfentrazone (Zeus) was effectively used as a preplant burndown treatment in the past; however, the registration of this product was discontinued in California in 2017.

It is common for a tank mix of trifluralin and s-metolachlor to be applied either before planting or after planting to control weeds before they emerge. Metribuzin can be applied and incorporated before planting to control weeds before they emerge, but this herbicide is fairly expensive, and maximum application amounts are restrictive. Pendimethalin may also be applied and incorporated into the soil as a preemergence treatment, but this herbicide is effective against fewer weeds than the other preemergence herbicides.

Carfentrazone may be applied as a preplant burndown treatment at least 1 day before transplanting. A tank mix of glyphosate and oxyfluorfen may also be applied at least 30 days before planting for both preemergence and postemergence weed control. If applied as a standalone treatment, glyphosate may be applied to beds at least 3 days before planting.

If precipitation is not sufficient to germinate weeds, beds may be preirrigated with sprinklers to initiate germination and a postemergence herbicide is applied to emerged weeds shortly afterward. This is also known as the stale seedbed method. The stale seedbed method is less commonly used in processing tomato that is planted in early spring, since the chance of rainfall is higher in early spring and preirrigation is less necessary for weed germination.

## Insect and Invertebrate Pest Management

In addition to eliminating weed competition, removing weeds in and around the field during fallow and before planting is an important management practice for various insect and invertebrate pests of processing tomato. Insecticides (e.g., diazinon) may be applied prior to planting in fields that regularly experience early-season damage from pests such as darkling beetles, symphylans, or wireworms.

## Vertebrate Pest Management

The fallow and preplant period is the most critical time for managing vertebrate pests, particularly burrowing rodents. Most rodenticide baits used to control burrowing rodents in processing tomato must be used during the fallow period or before planting. Burrow fumigation, though rarely used, can also only be done prior to planting. Burrowing rodents are also managed during this time by removing habitat that supports their populations (e.g., managing weeds, destroying burrows with cultivation and tillage). Trapping may also occur at this time. (See Foundation for a Pest Management Strategic Plan for more information.)

**Soil Tests**

Soil tests before planting are taken during the fall fallow period to assess nitrogen, phosphorus, and potassium concentrations, salinity, pH, and the presence of root-knot nematodes. Soil samples are taken by hand from the root zone (~12 inches deep in the beds).

**Fumigation**

Beds are sometimes fumigated before planting (either during the fall fallow period or in the late winter prior to planting) to reduce soilborne pathogens (such as those that cause corky root rot, southern blight and Verticillium wilt) or root-knot nematodes, though this practice has become less common. Fumigation can also control various weeds, but is not typically used specifically for weed management. Nutsedge was a major target pest for fumigation in the past, but there are currently other options that assist with nutsedge management (especially Dual Magnum preplant or at planting, and Sandea during the season). Metam sodium (Vapam) or metam potassium (K-Pam) are the main fumigants used in processing tomato, though 1,3-dichloropropene (Telone) may be used in some cases.

**Fertilizer Application**

Phosphorus is the main fertilizer applied to processing tomato before planting (sometimes at planting). It is applied close to the plant row or as a transplant drench.

In organic processing tomato, compost is applied during the fall fallow period in order to allow enough time for the product to break down into a form that can be used by the crop. Common types of compost applied in organic processing tomato may include chicken manure, steer manure, and seaweed soil amendments.

**Greenhouse Operations**

The vast majority of processing tomato in California is transplanted to simplify seedbed preparation, assist with stand establishment, enable the crop to better outcompete weeds, and expand the number of herbicide options that may be used. During the preplant period. transplants are grown in commercial greenhouse operations and delivered to the field near the expected planting time. Growers select and provide the seed to greenhouse operations, and young tomato plants are delivered to the field as plugs in seedling trays.

Grafting is not yet practiced for processing tomato transplants, but there is a growing interest in grafting as a means of increasing crop resistance to both soilborne and aboveground pests (especially pathogens). Challenges to grafting include lack of sufficient greenhouse space, lack of mechanization, high costs, and lack of resistant rootstocks and scions for major diseases (e.g., southern blight).

## Planting to Prebloom (0 to 4 weeks)

During this time, field activities include planting, monitoring for early-season invertebrate pests and diseases, applying insecticides and preventive bactericides (copper), taking whole-leaf samples to assess nutrient levels and make fertilizer application decisions, applying fertilizer, surveying and managing weeds (via herbicide application, cultivation, and hand weeding), and managing vertebrate pests. Nematodes may also be managed at this time if necessary, though they are typically managed prior to planting.

### Planting

The planting period depends on the contracted schedule with processor, the region, the weather conditions, and the expected pest problems. Historically, processing tomato was mostly direct-seeded and planting would occur as early as January. Because the vast majority of processing tomatoes are now transplanted, planting now occurs much later (see the Background and Overview section for more information on planting periods for each growing region). Planting may be delayed if there is a major issue with the delivered transplants (e.g., bacterial speck), but in most cases this is not possible due to insufficient supply of additional transplants.

Processing tomatoes are planted in either one or two rows per bed. The number of rows per bed depends on the tomato variety that is planted (which can depend on the preferences of the harvester or processor), the history of the field based on the grower's experience, and the irrigation method used by the grower. It may also be influenced by the type of cultural practices used and the pest problems that are expected to occur. Mechanical cultivation and hand weeding are easier in single-row tomatoes; whereas double-row tomatoes better compete with weeds and are less attractive to beet leafhopper due to their dense canopy cover.

All transplants are planted with hand-fed mechanical transplanters that have either finger type or rotary carousel transplanters. Eight to ten farmer workers input transplants into the mechanical transplanters while seated on the transplanting vehicle, while two to three additional workers walk behind the vehicle to ensure the transplants are secure in the ground after planting.

### Fertilizer Application

In conventional processing tomato, nitrogen may be applied at planting as a sidedressing based on soil tests. It may be applied again later in the season at different intervals (typically through the drip irrigation system) depending on the outcome of whole-leaf nutrient sampling.

### Insect and Invertebrate Pest Management

In the southern region, greenhouse operations often apply a systemic insecticide such as imidacloprid (Admire Pro) or cyantraniliprole (Verimark) to transplants prior to delivery. The purpose of this application is to prevent high infestations of pests such as beet leafhopper and whiteflies (see Efficacy Tables for more information on specific pesticides).

For the first several weeks after transplanting, critical insect pests to monitor include thrips, cutworms, darkling beetles, wireworms, and garden symphylans. Fields are typically monitored for pests once a week during this time. Monitoring usually consists of checking foliage for pests and their damage. Growers may also dig around weakened transplants to search for soil-dwelling invertebrate pests if they suspect infestations.

Insecticides may be applied during this time if early-season pests become too damaging (see Efficacy Tables and Foundation for a Pest Management Strategic Plan). Cutworms, darkling beetles, and thrips are often managed with insecticides during this time, while management for wireworms and garden symphylans is done before planting.

Preventive stink bug management can be especially crucial during this time, especially the elimination of weed hosts that facilitate stink bug infestations. If stink bugs are detected in the field early in the season, insecticide applications are sometimes necessary to reduce their damage later in the season.

**Disease Management**

Bacterial diseases (especially bacterial speck) are the greatest problem at this time, particularly when planting is done in early spring, when conditions are cooler and wetter. Bacterial diseases are less of a problem when the crop is planted later, such as in May. If conditions are expected to favor the development of bacterial diseases, growers may apply bactericides such as a tank mix of copper (Kocide) and mancozeb (Dithane). The thrips-vectored *Tomato spotted wilt virus* is also usually a problem during this time if thrips infestations are a problem.

Less common diseases that may appear at this time include corky root rot, late blight, and Verticillium wilt (though only late blight can be managed in-season).

**Weed Management**

Subsurface drip irrigation has reduced weed germination in processing tomato because the irrigation system keeps the tops of the beds dry. Most emerging weeds outside of the plant row can be controlled with mechanical cultivation while the crop is small. Many different types of cultivators may be used and may include double-disc openers and finger weeders. Weeds that emerge in the plant row are also removed by hand weeding or hand hoeing during the first two weeks after planting.

Common herbicides used during this time include rimsulfuron (Matrix) and halosulfuron (Sandea), especially for the purposes of managing emerged weeds such as nightshades and nutsedge. Metribuzin may be applied during this time if it was not applied before planting, or if the seasonal application rate otherwise has not been reached. Trifluralin (Treflan) or pendimethalin (Prowl H2O) may also be applied as a soil-incorporated preemergence application during the layby period (the time from transplanting until the first open flower) if not used before planting. Postemergence herbicides for grasses (such as clethodim or sethoxydim) may also be applied during this time, though this is less common.

**Nematode Management**

An in-season nematicide may be applied during this stage if nematodes are damaging the crop (See the Nematodes section of the Foundation for a Pest Management Strategic Plan for more information.)

**Vertebrate Pest Management**

Management of various vertebrate pests continues during this stage, but generally fewer options are available than during the fallow and preplant periods. After planting, fencing may be installed in areas that experience damage from deer or rabbits. However, damage from these pests is generally rare, and installing fencing is usually not economically feasible.

Some forms of burrowing rodent management can take place during this time, such as trapping and applying bait inside gopher burrows. (See the Foundation for a PMSP Vertebrates section for more information.)

## Bloom to Early Fruit Set (4 to 8 weeks)

Farming activities that take place from bloom to early fruit set include taking leaf samples for nutrient analysis, taking soil samples for nutrient analysis, applying fertilizer if necessary, monitoring for various pests, and applying insecticides, fungicides, and herbicides. Hand weeding may also be necessary at this time to eliminate solanaceous weeds and other difficult weeds such as velvetleaf. Vertebrate pests may also be managed as necessary during this time.

### Fertilizer Application

Whole-leaf sampling at this time reliably helps determine nitrogen deficiency and make nitrogen fertilizer application decisions, while preplant soil tests determine potassium levels. If necessary, nitrogen or potassium are applied through the irrigation system. For potassium, application occurs during early fruit set to increase yield and ensure consistent fruit color.

### Insect and Invertebrate Pest Management

Monitoring and managing thrips and their weed hosts continues during this time.

Stink bug monitoring occurs at this time, and insecticide application is often necessary to manage stink bugs at this stage. Monitoring for consperse stink bug also begins during this time (beginning at flowering) in order to catch infestations early and prevent an intolerable amount of damage to the fruit. Monitoring for stink bugs can involve placing pheromone traps in the field, though this is less common than sampling for stink bugs with a beating sheet or tray. In the northern region, growers may also monitor for lygus bug while monitoring for consperse stink bug.

In the southern region, this period is also critical for managing beet leafhopper, especially by applying malathion. Whiteflies may also require management at this time in the southern region, though they are generally much less damaging.

Management and removal of weeds that are hosts to insect pests such as thrips, leafhoppers, stink bugs and lygus bugs (in the northern region) also continues to occur at this time.

### Disease Management

Disease management from bloom to early fruit set largely focuses on monitoring for major diseases such as Fusarium wilt, Fusarium crown rot, powdery mildew, and southern blight. Fungicides may be applied to prevent powdery mildew in conditions that favor the development of the disease. Management of powdery mildew also helps to reduce sunburn and fruit rots later in the season.

Bacterial diseases such as bacterial spot and bacterial canker may also require management during this stage, depending on weather conditions. Less major diseases, such as Alternaria stem canker and late blight, may also be managed at this time in fields where they are a problem.

**Weed Management**

Mechanical cultivation and hand weeding may occur during this time. Mechanical cultivation becomes limited on the bed during this stage as the tomato vines grow longer. However, weeds that emerge in the furrows can still be controlled with cultivation.

Herbicides may be used in order to keep weed infestations at bay. Halosulfuron (Sandea), rimsulfuron (Matrix), and metribuzin (if maximum seasonal application rate has not been reached) are commonly applied during this time. Clethodim (Select Max) or sethoxydim (Poast) are applied if necessary for grass weeds without damaging the crop.

**Nematode Management**

Nematodes may require management with an in-season nematicide during this time if they were not managed earlier in the season and are causing damage.

**Vertebrate Pest Management**

Management of burrowing rodents may occur during this time as possible (see Foundation for a PMSP).

## Late Fruit Set to First Red Fruit (8 to 12 weeks)

Farming activities during late fruit set may include whole-leaf sampling for nutrient analysis, fertilizer application (if necessary based on leaf sampling and soil tests), monitoring and managing insect pests (including via insecticide application), monitoring and managing diseases (including via fungicide application), weed management, and vertebrate management.

### Fertilizer Application

Application of potassium fertilizer sometimes continues at this time based on the results of preplant soil tests, to reduce fruit color disorders. Nitrogen may be applied at late fruit set as well; it is usually not needed once fruit starts to ripen.

### Vine Training or Trimming

During fruit development, mechanical equipment is used to push the vines of the crop out of the furrow and onto the bed, or to trim excessive vine growth. This practice is used primarily to reduce fruit loss in the furrows during harvest, as well as improve air circulation in the crop canopy and reduce infection by fruit rots later in the season.

### Insect and Invertebrate Pest Management

Monitoring for and managing stink bug is crucial once the fruit reaches 1 inch in diameter. Insecticides are often applied for stink bugs during this time, though it is best to apply them earlier than this stage. Full coverage of insecticide applications on the crop can be much more difficult to achieve at this stage and later stages.

In the northern region, lygus bugs may also be monitored in the process of monitoring for stink bugs, but lygus tends to be a less significant pest. Lygus may require insecticide application in tomatoes grown for whole-peel processing, but in other cases is not usually a problem.

In the northern region, monitoring for armyworms, cutworms, tomato fruitworm eggs, potato aphid, and tomato russet mite is especially important during this time. Monitoring for armyworms and cutworms involves walking through the field, picking fruit (especially fruit touching the ground) and examining fruit for the caterpillars or their damage. Monitoring for potato aphid, fruitworm eggs, and russet mite requires examining the leaves. Insecticides or miticides (see Foundation for a PMSP and Efficacy Tables) may be applied if necessary.

In the southern region, whiteflies may continue to be monitored and managed during this time to prevent fruit color disorders.

### Disease Management

Powdery mildew is especially important to manage during this time (via vine trimming and preventive fungicide application) to prevent defoliation and sunburn damage and fruit rots. Other diseases that can cause major damage to the crop during this stage include southern blight and various Fusarium diseases (see Foundation for a Pest Management Strategic Plan section), but management of these diseases is not possible once they have developed.

Other less common diseases that may be managed during late fruit set include Alternaria stem canker, bacterial canker, bacterial spot, and late blight.

## Weed Management

Beginning at late fruit set and continuing until harvest, hand weeding is usually used to eliminate weeds from the beds and the seed line. The primary weeds that require hand weeding during this time include nightshades, groundcherries, field bindweed, volunteer sunflowers, and velvetleaf. Broomrape may be detected during hand-weeding activities in the areas that are currently affected by this weed.

Herbicides are rarely applied during this stage.

## Nematode Management

Nematodes may require management with an in-season nematicide during this time if they were not managed earlier in the season and are causing damage, but this becomes less necessary as fruit ripening begins.

## Vertebrate Pest Management

Management of burrowing rodents may occur during this time to the extent that is possible (see Foundation for a Pest Management Strategic Plan). If birds are a problem in the field (more often in the southern region), bird guns (noise-making devices) may be used during this time to scare birds away.

## First Red Fruit to Harvest (12 to 18 weeks)

Fruit ripener (ethrel) may be applied a few weeks before harvest in order to provide for even ripening to prepare for harvest. From first red fruit through fruit ripening, farming activities include monitoring and managing insect pests (including via insecticide application), monitoring and managing diseases (including via fungicide application), weed management (primarily hand weeding), and vertebrate pest management.

### Insect and Invertebrate Pest Management

At the first red fruit stage, growers or pest control advisers will monitor for pests once per week. Invertebrate pests that are managed during late fruit set may continue to be managed as fruit ripens. For stink bugs, management at this time is much less effective than managing at earlier stages.

### Disease Management

The most important diseases to monitor and manage from first red fruit up to harvest are powdery mildew and fruit rots. Sunburn prevention is also especially important at this stage in order to prevent fruit rots.

Fusarium diseases (especially *Fusarium falciforme*) and southern blight can cause significant damage during this time, but management of these diseases is not possible once they have developed.

### Weed Management

Hand weeding to remove major late-season weeds such as groundcherries, nightshades, velvetleaf, and other weeds from the bed continues during early fruit ripening.

### Vertebrate Pest Management

Burrowing rodents and birds may be managed at this time if necessary and possible (see Late Fruit Set to First Red Fruit and Foundation for a Pest Management Strategic Plan).

## Harvest and Postharvest (Fallow)

Processing tomatoes are harvested when fruit is ripe, and harvest must take place promptly after fruit ripening to prevent the development of black mold and other fruit rots (see Fruit Rots section of Foundation for a Pest Management Strategic Plan for more information).

All processing tomatoes in California are harvested mechanically. The crop is quickly transported to processing operations, where they are processed within 24 hours. Prior to processing, bulk loads are graded for fruit color, pH, soluble solids content (Brix), and defects at mandatory fruit inspection locations throughout the production areas.

After harvest is complete, various measures may be taken to mitigate pest problems for future processing tomatoes or other subsequent crops.

It is common for fields to be fallowed from fall through late winter or early spring before the next processing tomato season. In some cases, such as on farms that utilize conservation tillage, growers may plant a winter cover crop instead of leaving the field fallow.

### Weed Management

The harvest process can aid in subsequent weed management because it undercuts both the crop and any emerged weeds on the bed. For further information on weed management after harvest (during the fallow period), refer to the Weed Management (*Fallow*) section of Fallow and Preplant.

### Crop Rotation

While crop rotation in processing tomato systems has become less common with drip irrigation, growers do still occasionally use it to manage pest problems. Processing tomatoes may be grown for two consecutive seasons following installation of drip tape; afterward, other crops may be grown for one to three years. Growers in the northern region may rotate to sunflowers, corn, or wheat if *Fusarium* has been a problem in the field, although the effectiveness of this practice is not known. In the southern region, growers may rotate to wheat if processing tomatoes were damaged by root-knot nematodes in the previous season, or to cotton or safflower if darkling beetles have been a problem.

Processing tomato farms under conservation tillage or no-till management may be planted with cover crops during the fall and winter. Fall cover crops may include triticale, barley, vetch (fava beans), or another type of legume.

Other information for management activities that take place after harvest and on fall fallow beds can be found in the first subsection of this section, Fallow and Preplant.

# Appendix I: Tables of Pest Occurrence and Management

## Insect and Other Invertebrate Pests (Non-Virus Transmitting)

P = The pest is present in the crop and/or damaging the crop at this time.
M = Management of this pest may occur during this time. Management may include monitoring and prevention in addition to other management methods. See the Foundation for a Pest Management Strategic Plan for more stage-specific information.

| **Insect Pest** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest |
|---|---|---|---|---|---|---|---|---|
| Armyworms | Northern | | | | P, M | P, M | | |
| Cutworms | Northern | M | P, M | | P, M | | | |
| Darkling beetles | Statewide | M | P, M | | | | | M |
| Garden symphylans | Statewide | P, M | P | | | | | M |
| Lygus bugs | Northern | | | P, M | P, M | P, M | | |
| Potato aphid | Statewide | M | | | P, M | P, M | | |
| Stink bugs | Statewide, but greater damage in southern region | M | P, M | P, M | P, M | P, M | M | |
| Tomato fruitworm | Northern | | | | P, M | P, M | | |
| Tomato russet mite | Northern | | | P | P, M | P, M | | |
| Whiteflies | Southern | M | P, M | P, M | P, M | P, M | | |
| Wireworms | Northern | P, M | P | | | | | |

## Virus-Transmitting Insects and Associated Viruses

I = Insect vector is present in the crop at this time.
V = Virus symptoms may be present in the crop at this time.
M = Management for the insect vector and/or virus occurs at this time. Management may include monitoring and prevention in addition to other management methods. See the Foundation for a Pest Management Strategic Plan for more stage-specific information.

Note: *Tomato yellow leaf curl virus* is not included due to its relative containment. Whiteflies are included in Table 2.

| **Insect Pest and Virus** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest |
|---|---|---|---|---|---|---|---|---|
| Beet leafhopper and curly top | Southern | M | I, V, M | I, V, M | | | | M |
| Green peach aphid and alfalfa mosaic | Statewide | M | I, V | | | | | |
| Thrips and tomato spotted wilt | Statewide | M | I, V, M | I, V, M | V | V | | |

## Bacterial and Fungal Diseases

P = Disease symptoms may be present during this time.
M = Disease or pathogen may be managed during this time. Management may include monitoring and prevention in addition to other management methods. See the Foundation for a Pest Management Strategic Plan for more stage-specific information.

| **Disease** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest |
|---|---|---|---|---|---|---|---|---|
| Alternaria stem canker | Southern | M | | P, M | P, M | P, M | | |

| **Disease** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest |
|---|---|---|---|---|---|---|---|---|
| Bacterial canker | Southern | M | P, M | P, M | P, M | | | |
| Bacterial speck | Statewide | M | P, M | | | | | |
| Bacterial spot | Southern | M | P, M | P, M | P, M | P | | |
| Corky root rot | Northern | M | P | P | | | | |
| Fusarium crown and root rot | Statewide | M | | P | P | | | |
| *Fusarium falciforme* | Statewide | | | | P | P | P | |
| Fusarium foot rot | Northern | | | P | P | P | | |
| Fusarium wilt | Statewide | M | | P | P | P | P | |
| Fruit rots (including black mold) | Statewide (though more severe in the north) | | M | M | M | P, M | P, M | |
| Late blight | Statewide | | P, M | P, M | P, M | | | |
| Powdery mildew | Statewide | | | P, M | P, M | P, M | P | |
| Southern blight | Statewide | M | M | P, M | P, M | P | | |
| Verticillium wilt | Northern | M | P, M | P, M | | | | |

## Root-Knot Nematodes

| | **Region** | **Preplant** | **Planting to Prebloom** | **Bloom to Early Fruit Set** | **Late Fruit Set** | **First Red Fruit** | **Harvest** | **Postharvest** |
|---|---|---|---|---|---|---|---|---|
| Root-knot nematodes | Statewide | M | P, M | P, M | P, M | | | M |

## Weed Occurrence

P = The weed may be present in the crop at this time.

Note, timing of management is not included in this table because weeds are mostly managed collectively rather than individually. See Farming and IPM Practices section for general weed management practices used at each crop stage. See Foundation for a PMSP and Efficacy Tables for more information on the effectiveness of herbicides or other management practices on specific weeds.

| **Weed** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest (Fallow) |
|---|---|---|---|---|---|---|---|---|
| Alkali mallow | Southern | P | P | P | P | P | P | P |
| Alkaliweed | Southern | P | P | P | P | P | P | P |
| Broomrape | Statewide | | | P | P | P | P | |
| Dodders | Northern | | P | P | P | P | P | |
| Field bindweed | Statewide | P | P | P | P | P | P | P |
| Groundcherries | Northern | | | | P | P | P | |
| Hairy fleabane | Statewide | P | | P | P | P | P | |
| Horseweed | Statewide | P | | | P | P | P | |
| Italian ryegrass | Northern | P | P | P | P | P | | |
| Johnsongrass | Northern | P | P | P | P | P | P | P |
| Lambsquarters | Southern | P | P | P | P | P | P | |

| **Weed** | **Region** | Preplant | Planting to Prebloom | Bloom to Early Fruit Set | Late Fruit Set | First Red Fruit | Harvest | Postharvest (Fallow) |
|---|---|---|---|---|---|---|---|---|
| Little mallow | Statewide | P | P | P | P | P | P | P |
| Nettleleaf goosefoot | Statewide | P | P | P | P | P | P | |
| Nightshades | Statewide | P | P | P | P | P | P | |
| Perennial pepperweed | Southern | P | P | P | P | P | P | |
| Russian thistle | Statewide | P | P | P | P | P | P | |
| Sowthistles | Northern | P | P | P | P | P | P | P |
| Sunflowers | Northern | P | P | P | P | P | P | P |
| Velvetleaf | Northern | | | | P | P | P | |
| Yellow nutsedge | Statewide | P | P | P | P | P | P | P |

# Appendix II: Efficacy Tables

Data based on collective field observations and experiments by growers, pest control advisers, and University of California Cooperative Extension advisors and specialists.

## INSECT PESTS

### Table 1a. Efficacy of insecticides used in California processing tomatoes.

Rating System: E = Excellent, G = Good, F = Fair, NE = Not effective, U = Unknown, NU = Not used, ? = Not enough information.

# = Rating is primarily for organic systems.

| **Insecticide** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies[2] | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| abamectin (Agri-Mek) | G | | | | | | | | | | | F | | | |
| acetamiprid (Assail) | | | | | | G | | G | | | | | | G | |
| azadirachtin (Debug) | G# | F–G# | G# | | | G# | | G# | | | G# | | G# | | |
| *Bacillus thuringiensis aizawai* | G | | | | | | | | | | | | G | | |
| *Bacillus thuringiensis kurstaki* | | | | | | | | | | | F–G | | | | |

| **Insecticide** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies[2] | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| beta-cyfluthrin (Baythroid) | | | | | | | | | U[6] | | | | | | |
| buprofezin (Courier) | | | | | | | | | | | | | | G | |
| *Burkholderia* spp., strain A396 (Venerate) | | F# | | | | | | | | | | | | | |
| carbaryl (Sevin) bait | | | G | NE[5]–G | | | | | | | | | | | |
| chlorantraniliprole (Coragen) | | F–G | | | | | | | | | G | | | | |
| clothianidin (Belay) | | | | | | | G | | NE[4] | | | | | | |
| cyantraniliprole (Verimark) | | F–G | | | | | | | | F | | | | | |
| diazinon | | | | G | G | | | | | | | | | | G |
| dimethoate | | | | | | | F–G | | NE–G | G | | | | | |
| dinotefuran (Venom) | | G | | | | | | | G | | | | | G | |
| emamectin benzoate (Proclaim) | G | | | | | | | | | | G | | | | |
| esfenvalerate (Asana) | | | | G* | | | | | U, NE | | | | | | |
| fenpropathrin (Danitol) | | | | | | | | | G | | | | | | |
| flonicamid (Beleaf) | | | | | | G | G | G | NE | | | | | | |

| **Insecticide** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies[2] | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| flupyradifurone (Sivanto) | | | | | | | | | | | | | | G | |
| imidacloprid (Admire Pro) | | G | | | | G | | G | F[6] | | | | | G | |
| indoxacarb (Avaunt) | G | | | | | | | | | | | | | | |
| insecticidal soap (M-Pede) | | | | | | F–G# | B | F–G# | NE | | | | | | |
| lambda-cyhalothrin (Warrior) | | | | | | | | | F–G[4] | | | | | | |
| malathion | | E | | | | | | | | G | | | | | |
| methomyl (Lannate) | F–G | | | | | | G | | NE | G | | | G | | |
| methoxyfenozide (Intrepid) | G | | | | | | | | | | G | | G | | |
| neem oil (Trilogy) | | F# | | | | | | | | | | | | | |
| oxamyl (Vydate) | | | | | | NU | | | | | | | | | |
| pymetrozine (Fulfill) | | | | | | F | | F | | | | | | | |
| pyrethrins (PyGanic) | | G# | | | | F–G# | | F–G# | | | F–G# | | | | |
| pyrethroids (none specified) | | G | | | | | | | | NE | | | | | |
| pyriproxyfen (Knack) | | | | | | | | | | | | | | G | |

| **Insecticide** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies[2] | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| rosemary/ peppermint oil (Ecotrol) | | | | | | | | F | | | | | | | |
| spinosad bait (Seduce) | | | G | NE[5] | | | | | | | | | | | |
| spinosad spray[3] (Entrust, Success) | G | | G | | | | | | | G | F–G | | F–G | | |
| spinetoram (Radiant) | G | | | | | | | | | G | F–G | | | | |
| spirotetramat (Movento) | | | | | | G | | G | | | | | | | |
| sulfur | | | | | | | | | | | | G–E | | | |
| thiamethoxam (Actara, Platinum) | | G | | | | | | | | | | | | | |
| thyme oil (Proud) | | | | | | F–G# | | F–G# | | | | | | | |
| zeta-cypermethrin (Mustang) | | | | | G | | | | | | | | | | |
| abamectin (Agri-Mek) | G | | | | | | | | | | | F | | | |

[1] = Thorough coverage is crucial for insecticide efficacy against stink bugs. Insecticide efficacy tends to be higher with an air-assisted sprayer.
[2] = Insecticide only necessary if processing tomatoes are near cotton fields.
[3] = Entrust is the organically acceptable formulation of spinosad; Success is not organically certified.
[4] = Efficacy against consperse stink bug is better when a pyrethroid (especially lambda-cyhalothrin) is combined with a neonicotinoid.

[5] = Observed ineffectiveness may have been due to bait quality or improper application timing.
[6] = Has been found to be effective in premix of imidacloprid and beta-cyfluthrin (trade name Leverage); rating in the table is that of a standalone application.
* = Esfenvalerate is effective against darkling beetles when applied through the sprinkler system.

**Table 1b. Efficacy of nonchemical management aids used for insect pests of California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, U = Unknown, NE = Not effective, NU = Not used.

# = Rating is primarily for organic systems.

| **Nonchemical Management Tool** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avoid planting near well known crop hosts | | | | | | F–G[6] | | F–G[6] | | NE–G[9] | F–G | | | G[10] | |
| Allow plant residue to completely break down preplant | | | F–G | G–E | G/U[3] | | | | | | | | | | F–G |
| Biological control | F–G | | | | | F–G | | NE–G | NE–F[8] | | F–G | | F–G | NE–F | |
| Crop rotation | | | | F–G[2] | U | | | | | | | | | | |
| Cover crops | | | | NE | | | | | | | | | | | |
| Degree-day models | | | | | | | | | NU | | | | | | |

| **Nonchemical Management Tool** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Destroy crop residue after harvest | | | F–G | | | | | | | | | | | | F–G |
| Exclusion (water-filled ditches) | | | | NE–G# | | | | | | | | | | | |
| Fertility management | | | | | | F–G | | F–G | | | | | | | |
| Host-free period | | | | | | | | | NE–G | | | | | | |
| Higher plant density | | F–G | | | | | | | | | | | | | |
| Monitoring (general) | G | | | | | F–G | | F–G | | G | | | G | G | |
| Lure traps | | | | | | | | | F–G, NU | | | | | | |
| Potato or carrot bait | | | | | NU | | | | | | | | | | NU |
| Sweep nets | | NE | | | | | | | | | | | | | |
| Sticky traps | | G | | | | | | | | | | | | | |
| Inspect plants | | | | G | | | | | NE | | | F–G | | | |
| Treatment thresholds | G | | | | | | | F | NE | | G | | G | | |
| Planting date | | | | | G[4] | | | | | NE–G[13] | | | | G[11] | |
| Preplant cultivation | | | G | G | | | | | | | | | | | |

| **Nonchemical Management Tool** | Beet armyworm | Beet leafhopper | Cutworms | Darkling beetles | Garden symphylan | Green peach aphid | Lygus bugs | Potato aphid | Stink bugs | Thrips | Tomato fruitworm | Tomato russet mite | Western yellowstriped armyworm | Whiteflies | Wireworms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reflective mulches | | | | | | NU | | | | | | | | NU | |
| Remove weed hosts | | F–G | G | G | | | | | G[12] | G | | F–G | | G[14] | |
| Remove overwintering habitat | | | | G | | | | | G | | | | | | |
| Sprinkler irrigation | | | | G# | | | | | | | | | | | |
| Trap crops | | NE–G[1] | | | | | | | | | | | | | |
| Water management | | | | | F–G[5] | F–G[7] | | F–G | | | | | | | |

[1] = Depends on the trap crop. Red beet trap crop has been used effectively with few observations of being a virus reservoir. Sugar beet trap crop may be less effective, greater potential as a reservoir for *Beet curly top virus*. Safflower ineffective.

[2] = Rotate to cotton or safflower, do not plant field to tomatoes for more than 1 year.

[3] = Northern region stressed significance of allow plant residue to decompose before planting to reduce symphylans. Southern region had no information about the practice.

[4] = Planting one crop immediately after the other increases problems from symphylans; a break before planting reduces infestations.

[5] = Increased soil moisture may make plants more resilient against symphylan damage in the southern growing regions. In the northern growing region, greater soil moisture may increase problems from insect pests.

[6] = Green peach aphid and potato aphid infestations are greater in processing tomato fields planted near alfalfa.

[7] = In the northern region, increased moisture in the field is associated with higher aphid infestations.

[8] = Biological control somewhat effective but does not keep stink bug numbers low enough to avoid damage.

[9] = Host plants for thrips in the southern region especially include greenhouse operations, ornamental plants, raddichio, and weeds in walnut orchards. In the northern region, fava bean cover crops may be especially important to avoid. Thrips also have many other host plants that may increase infestations in processing tomato.

[10] = For whiteflies, it is especially effective to avoid planting processing tomatoes near cotton.

[11] = To avoid the increase in whiteflies, plant early.

[12] = It is necessary to remove older weeds (which support stink bug) from fall-planted or permanent crops. Beginning in February, weeds that are large enough to support stink bug populations should be removed.

[13] = Effectiveness of adjusting planting dates varies significantly based on what other activities may occur at that time. Planting earlier in the southern region generally helps to reduce damage from thrips, but this practice is not effective if weed hosts of thrips are removed in neighboring crops are being removed at that time. Removal of weed hosts in neighboring crops increases thrips infestations in processing tomato.

[14] = For whiteflies, remove all host weeds and destroy field bindweed including when processing tomatoes are not in the field.

## DISEASES

### Table 2a. Efficacy of bactericides and fungicides used in California processing tomatoes.

Rating System: E = Excellent, G = Good, F = Fair, U = Unknown, NE = Not effective, NU = Not used.

| **Fungicides/ Bactericides** | Alternaria stem canker[2] | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Gray mold | Late blight | Powdery mildew | Southern blight | Verticillium wilt | Water mold (fruit rot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| azoxystrobin (Quadris) | | | | | G | | | | | | | | G | | | |

| **Fungicides/ Bactericides** | Alternaria stem canker[2] | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Gray mold | Late blight | Powdery mildew | Southern blight | Verticillium wilt | Water mold (fruit rot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| azoxystrobin/ difenoconazole (Quadris Top) | | | | | G | | | | | | | | G–E | | | |
| *Bacillus pumilis* (Sonata) | | | | | | | | | | | | | U | | | |
| *Bacillus subtilis* (Serenade) | | | | | | | | | | | | | F | | | |
| chlorothalonil (Bravo) | | | | | G–E | | | | | | | NE–G[2] | | | | |
| copper hydroxide (Kocide) | | F | F–G[1] | F–G[1] | | | | | | | | | | | | |
| cyflufenamid (Torino) | | | | | | | | | | | | | G | | | |
| famoxadone + cymoxanil (Tanos) | | | | | | | | | | | | F–G | | | | |
| fluopyram/ trifloxystrobin (Luna Sensation) | | | | | | | | | | | | | G–E | | | |
| fluxapyroxad/ pyraclostrobin (Priaxor) | | | | | G | | | | | | | | G–E | | | |
| mancozeb (Dithane) | | | G | G | | | | | | | | | | | | |
| metam sodium (Vapam) | | | | | | G | | | | NU | | | | F–G | G | |
| metam potassium (K-Pam) | | | | | | G | | | | NU | | | | G | G | |

| **Fungicides/ Bactericides** | Alternaria stem canker[2] | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Gray mold | Late blight | Powdery mildew | Southern blight | Verticillium wilt | Water mold (fruit rot) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| myclobutanil (Rally) | | | | | | | | | | | | | G | | | |
| penthiopyrad (Fontelis) | | | | | F | | | | | | | | F–E | NE | | |
| pyraclostrobin (Cabrio) | | | | | F | | | | | | | | G | | | |
| sulfur | | | | | | | | | | | | | G–E | | | |
| sulfur, liquid (Thiolex) | | | | | | | | | | | | | NE–F | | | |

[1] More effective against bacterial speck when mixed with mancozeb.
[2] See fungicide efficacy for black mold.

**Table 2b. Nonchemical management aids used for bacterial and fungal diseases of California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, U = Unknown, NE = Not effective, NU = Not used. B = Blank.

| **Nonchemical aids to IPM of bacterial and fungal diseases** | Alternaria stem canker | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown and root rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Fruit rots | Late blight | Phytophthora root rot | Powdery mildew | Southern blight | Verticillium wilt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allow crop residue to decompose completely before planting | | | | | | | F–G | | | | | | | | | |
| Avoid root-knot nematode infestations | | | | | | | F–G | | | F–G | | | | | | |
| Avoid sprinkler irrigation | G | | F–G | G | G | | F–G | | | | G | G | | F–G | F–G | |
| Avoid working in the field when wet | | G | G | G | | | | | | | | | | | | |
| Cover cropping | | | | | | | | | | | | | | | NU | |
| Crop rotation | | G/NU | F/NU | | | | G[3] | | G | U | | | | | NE–F[6] | |
| Deep tilling/plowing | | | | | | G | | | | | | | | | NU/NE | |
| Degree-days | | | | | | | | | | | | | | NU | | |
| Fertility management | F–G | | | | F | F | F | | F | F | F | F | F | F | F | F |

| **Nonchemical aids to IPM of bacterial and fungal diseases** | Alternaria stem canker | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown and root rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Fruit rots | Late blight | Phytophthora root rot | Powdery mildew | Southern blight | Verticillium wilt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Higher beds (furrow-irrigated tomatoes) | | | | | | | | | | | G | | | | | |
| Keep beds dry | | | | | E | | | | | | G | | | | G | |
| Maintain good canopy cover | | | | | G | | | | | | G | | | | | |
| Late-season vine trimming | | | | | F–G | | | | | | F–G | | | | | |
| Monitor potato fields near tomato | | | | | | | | | | | | G | | | | |
| Pathogen-free seed/transplants | | G–E | G–E | G | | | | | | | | | | | | |
| Planting date | | | F–G[1] | F–G[1] | | | | | | | | | | | G[4] | |
| Planting density/spacing | | | | | | | | | | | G[5] | | | | | |
| Reduce sunburn | | | | | G | | | | | | G | | | | | |
| Resistant/tolerant varieties | | | NE | | F–G | | F–E | | | F–E | G | | | | | |
| Sanitation (general) | F–G | F–G | F–G | F–G | F–G | NE–F | NE–F | | F–G | NE–G | | F–G | NE | NE–F | NE–G | F–G |

| **Nonchemical aids to IPM of bacterial and fungal diseases** | Alternaria stem canker | Bacterial canker | Bacterial speck | Bacterial spot | Black mold | Corky root rot | Fusarium crown and root rot | *Fusarium falciforme* | Fusarium foot rot | Fusarium wilt | Fruit rots | Late blight | Phytophthora root rot | Powdery mildew | Southern blight | Verticillium wilt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clean equipment/ machinery | | | | | | | | | | U | | | | | | |
| Disinfect benches and hoses | | G | G | G | | | | | | | | | | | | |
| Soak seed in hot water | | NU | | | | | | | | | | | | | | |
| Steam potting flats | | G | G | G | | | | | | | | | | | | |
| Timely harvest | | | | | G[7] | | | | | | G[7] | | | | | |
| Water management | | F–G | F–G | | | F–G | NE–G | | NE–G | NE–G | F–G | | G–E | F–G | NE–G | NE–G |
| Weed management | | | G[2] | | G | | | | | | G | G[2] | | | | |

[1] Delay planting to avoid this disease. (Note that planting dates cannot always be adjusted due to contracts with processors.)
[2] Remove solanaceous weeds especially.
[3] Rotate out of tomatoes to manage this disease.
[4] Plant early to avoid damage from southern blight.
[5] Reduced planting density increases air circulation in the canopy and helps prevent the development of this disease.
[6] Because southern blight has so many hosts, crop rotation is not usually effective. However, rotation with corn or small grains can reduce inoculum after a few years.
[7] Timing of harvest is not always up to the grower due to contracts with processors.

**Table 2c. Efficacy of management tactics for viral diseases of California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, U = Unknown, NE = Not effective, ? = Not enough information.

| **Management tactics for reducing viral diseases** | Alfalfa mosaic | Curly top | Tomato spotted wilt |
|---|---|---|---|
| Avoid fields with history of the virus | NE | F | NE |
| Avoid planting next to alfalfa | E | | |
| Inspect transplants | | | NU |
| Manage insect vectors* | NE | F–G | G–E |
| Manage weed hosts | | | G? |
| Remove infected plants during 1st weeding | | | U |
| Resistant varieties | | | G–E[1] |
| Systemic insecticides | | F–G | F |

* See efficacy tables for insect pests on efficacy of management for insect vectors.

[1] Management method is excellent if the strain of the virus is not one that can break resistance.

## NEMATODE PESTS

**Table 3a. Efficacy of nematicides used in California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, U = Unknown, NE = Not effective, NU = Not used.

| **Active ingredient (example trade name)** | Root-knot nematodes |
|---|---|
| 1,3-dichloropropene (Telone) | E |
| fluensulfone (Nimitz) | E |
| fluopyram (Velum One) | G |
| metam sodium (Vapam) | G |
| metam potassium (K-Pam) | G |
| oxamyl (Vydate)[1] | G |

[1] = Applied for nematode infestations during the growing season only.

**Table 3b. Efficacy of nonchemical management aids used for nematode pests in California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, NE = Not effective, U = Unknown, NU = Not used.

| **Nonchemical management tools for nematode IPM in processing tomatoes** | Root-knot nematodes |
|---|---|
| Avoid planting in sandy soils[1] | G |
| Crop rotation | G[2] |
| Fallowing | NU |
| Look for galls on weed hosts | NU |
| Sample for nematodes before planting | G |

| **Nonchemical management tools for nematode IPM in processing tomatoes** | Root-knot nematodes |
|---|---|
| Resistant varieties | U[3] |
| Soil solarization | NU/NE |
| Treatment thresholds | NU |

[1] In the southern region, avoiding sandy soils may be associated with fewer nematode problems.
[2] Rotating to wheat helps reduce infestations of root-knot nematodes.
[3] Resistance breaking tends to happen under higher temperatures or when the crop is otherwise stressed.

## WEED PESTS

**Table 4a. Efficacy of herbicides used in California processing tomatoes.**

Rating system: E = Excellent, G = Good, F = Fair, NE = Not effective, NU = Not used, U = Unknown, ? = Not enough information.

For more information on efficacy for specific weeds, visit the UC IPM Pest Management Guidelines for Tomato (Susceptibility of Weeds to Herbicide Control: ipm.ucanr.edu/agriculture/tomato/Susceptibility-of-Weeds-to-Herbicide-Control/

| Timing | Active ingredient (example trade name) | WSSA MOA # | Annual weeds | Perennial weeds | Weed specifics and other notes |
|---|---|---|---|---|---|
| Fallow period | glufosinate (Rely) | 10 | G | NE | Burndown herbicide for emerged, young weeds. Must be applied at least 180 days before planting processing tomato. |
| | paraquat (Gramoxone SL 2.0) | 22 | G | NE | Burndown herbicide for emerged weeds. Annual broadleaf weeds, annual grasses and perennial seedlings. |
| | flumioxazin (Chateau SW) | 14 | G | NE | Controls weeds before they emerge. Controls common chickweed and little mallow. Must be applied at least 2 months before planting. |
| | glyphosate (Roundup PowerMax) | 9 | G | G | Burndown herbicide for emerged weeds. Suppresses field bindweed (in bloom) and controls many other weeds. May not be effective against hairy fleabane, horseweed, Italian ryegrass, and little mallow (larger plants). |
| | oxyfluorfen (Goal 2XL) | 14 | G | NE | Controls little mallow. Must be applied at least 30 days before transplanting tomato. Sometimes applied in a tank mix with glyphosate. |

| Timing | Active ingredient (example trade name) | WSSA MOA # | Annual weeds | Perennial weeds | Weed specifics and other notes |
|---|---|---|---|---|---|
| Preplant | carfentrazone (Shark EW) | 14 | NE–G | NE | Burndown herbicide for emerged weeds. Must be applied at least 1 day before transplanting. Controls solanaceous weeds and velvetleaf. Effective against annual broadleaf weeds but not annual grasses. More often used closer to the planting period, but sometimes applied during fallow. |
| | glyphosate (Roundup PowerMax) | 9 | G | G | Burndown herbicide for emerged weeds. Suppresses field bindweed (in bloom) and controls most other weeds. May not be effective against hairy fleabane, horseweed, and Italian ryegrass. Must be applied at least 3 days before planting. |
| | oxyfluorfen (Goal 2XL) | 14 | G | NE | Controls little mallow. Must be applied at least 30 days before transplanting tomato. Sometimes applied in a tank mix with glyphosate. |
| | trifluralin (Treflan HFP) + s-metolachlor (Dual Magnum) tank mix | 3 + 15 | G | G | Primarily preemergence herbicides. Controls goosefoot, nutsedge, annual grasses, and nightshades, and Russian thistle. Provides some bindweed suppression and some control of lambsquarters. Usually preplant incorporated within 14 days of planting. |
| | pendimethalin (Prowl H2O) | 3 | NE–G | NE | Preemergence herbicide. Controls grasses. Not very effective against broadleaf weeds. |
| | metribuzin | 5 | G | NE | Can be applied before planting, but not as commonly used preplant as other herbicides. Controls hairy nightshade, volunteer melons, sowthistles, sunflowers, velvetleaf, goosefoot, and various other weeds. Only partial control of hairy fleabane and black nightshade. Most effective when weeds are less than 1 inch tall. This |

| Timing | Active ingredient (example trade name) | WSSA MOA # | Annual weeds | Perennial weeds | Weed specifics and other notes |
|---|---|---|---|---|---|
| | | | | | herbicide cannot be used on processing tomato in Kern County. Application rate of 0.6–1.3 lb per acre; however, no more than 1.3 lb per acre can be applied per season. Relatively expensive herbicide. |
| Preplant fumigants | metam sodium or metam potassium (Vapam or K-Pam) | 26 | G | NE–G | Fumigation not typically done for weed control. Fumigants are expensive and restricted pesticides. May be used during either fallow or preplant. Only partially effective against mature perennial weeds. |
| Postplant | halosulfuron (Sandea)[1] | 2 | G | G | Postemergence herbicide. Often applied at layby[2]. Controls goosefoot, nutsedge, sunflowers, velvetleaf. Can cause crop damage if the crop is stressed. |
| | rimsulfuron (Matrix) | 2 | G | NE | Herbicide with preemergence and postemergence activity, though typically applied as a postemergence treatment (for weed seedlings). Controls groundcherries, nightshades, and pigweeds. Provides partial control of dodder. Provides partial control of lambsquarters. Preharvest interval of 45 days. Can marginally damage the crop under conditions of crop stress. Sometimes applied preplant. No more than three applications allowed per year. |
| | metribuzin | 5 | G | NE | Primarily used as a postemergence herbicide, but also has preemergence activity. Controls hairy nightshade, volunteer melons, sowthistles, sunflowers, velvetleaf, goosefoot, and various other weeds. Only partial control of hairy fleabane and black nightshade. This herbicide cannot be used on processing tomato in Kern County. Application rate of 0.6–1.3 lb per acre; however, no |

| Timing | Active ingredient (example trade name) | WSSA MOA # | Annual weeds | Perennial weeds | Weed specifics and other notes |
|---|---|---|---|---|---|
| | | | | | more than 1.3 lb per acre can be applied per season. Can cause crop injury (see label for specific situations that cause crop injury). Relatively expensive herbicide. |
| | clethodim (Select Max) | 1 | NE–G | NE–G | Postemergence herbicide. Controls grasses only (not effective against broadleaf weeds). Effective against some perennial grasses, but only at the seedling stage. Preharvest interval of 20 days. |
| | sethoxydim (Poast) | 1 | G | NE–F | Postemergence herbicide. Controls grasses only (mostly annual grasses). Effective against some perennial grasses, but usually at the seedling stage (exception: Johnsongrass). Can be used as a rescue treatment for grass infestations during the season, though not usually necessary. |
| | trifluralin (Treflan HFP) | 3 | G | G | Preemergence herbicide. Controls annual grasses, nightshades, and Russian thistle. Provides some bindweed suppression. Can only be applied after planting if not used preplant.  Provide effective control for grasses and broadleaf weeds for a long period of time. |

[1] = Application of this herbicide when tomatoes are under stress can lead to crop damage, including stunting and chlorosis. Some varieties are more sensitive than others.
[2] = Layby in transplanted processing tomato is defined as the time from transplanting until the first flower opens.

More information on herbicide efficacy can be found at the *Pest Management Guidelines: Tomato*, Susceptibility of Weeds to Herbicide Control.

**Table 4b. Efficacy of nonchemical management aids for weeds in California processing tomatoes.**

Rating system: E = Excellent, G = Good, F = Fair, NE = Not effective, U = Unknown, NU = Not used.

| **Nonchemical management tools for weed IPM in processing tomatoes** | Annual weeds | Perennial weeds |
|---|---|---|
| Crop rotation | G–E[3] | G–E[3] |
| Cover crops | NE–G[4] | NE–G[4] |
| Cultivation | G[4] | G[4] |
| Deep plowing | NU | NU |
| Flaming | NU | NU |
| Hand-weeding | G[4] | G[4] |
| Keep beds dry[1] | F–G | NE–F |
| Plant into weed-free ground[2] | G–E | G–E |
| Soil solarization | NU[5] | NU[5] |
| Stale seedbed method | F–G | F |
| Undercutting (during harvest) | F–G | F |

[1] The use of subsurface drip irrigation is the main means of keeping bed tops dry.

[2] This practice is especially important in organic processing tomatoes.

[3] "Excellent" rating refers to rotation to Roundup-ready crops in the southern region.

[4] Not effective against field bindweed.

[5] Solarization is usually not possible in processing tomato because the crop must be grown at the time of the year that would be most ideal for solarizing soil.

## VERTEBRATE PESTS

**Table 5a. Efficacy of management tactics for vertebrate pests of California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, NE = Not Effective, U = Unknown, NU = Not used.

| **Management tools for control of vertebrate pests in processing tomatoes** | Birds | Coyotes | Deer | Gophers | Ground Squirrels | Rabbits | Voles |
|---|---|---|---|---|---|---|---|
| Owl boxes near orchards | | | | U/G[1] | NE–F[1] | NE | U/G[1] |
| Fencing[2] | | | G/NU | NE | NE | G/NU | F/NU |
| Shooting | F/NU | E[3] | | | F/NU[4] | F/NU[4] | |
| Flood irrigation | | | | E/NU[5] | E/NU[5] | | E/NU[5] |
| Explosive devices | | | | NU | NU | | NU |
| Monitoring | G | | | G | G | | G |
| Removing or modifying habitat | G | | | G | G | G | G |
| Noisemakers (guns) | G | | F/NU | | | | |
| Traps | NU | NU | | G–E | NE–G[6] | NE | NE–G[7] |

[1] Though the extent to which owls reduce various rodent pests in fields not yet known, fields that are near orchards that have owl boxes are generally experienced to have less rodent damage. Owls have less impact on ground squirrel populations, since owls and ground squirrels are active at different times of the day.
[2] Though fencing can be effective for some pests listed here, it is generally too expensive to be used.
[3] Shooting is very effective against coyotes, but removing coyotes also increases rodent problems.
[4] Shooting ground squirrels and rabbits can be fairly effective when numbers are low, but generally this approach is not practical.
[5] Though flood irrigation is excellent at controlling burrowing rodents, increasing water scarcity has eliminated this practice as a management option.
[6] Traps are only effective when ground squirrel numbers are low.

[7] Traps are primarily used to detect voles rather than reduce their populations. Traps are effective at detecting voles but cannot be used to practically manage vole populations due to the high numbers of voles that are typically present in an infested field.

**Table 5b. Efficacy of rodenticides (both baits and burrow fumigants) used for burrowing rodents in California processing tomatoes.**

Rating System: E = Excellent, G = Good, F = Fair, NE = Not effective, U = Unknown, NU = Not used

| **Rodenticide** | Gophers | Ground squirrels | Voles |
|---|---|---|---|
| aluminum phosphide* | E/NU[1] | E/NU[1] | NE/NU |
| carbon monoxide/carbon dioxide | F–G /NU[2] | E/NU[2] | NU |
| chlorophacinone | NE–F | G–E | G |
| diphacinone | NE–F | G–E | G |
| repellants | NE/U | NE/NU | NE/NU |
| strychnine[3] | G/NU | NU | NU |
| zinc phosphide | NE–F | G | G |

* Burrow fumigant.
[1] Though aluminum phosphide is effective against gophers and ground squirrels, it is not used in California processing tomato due to worker safety risks.
[2] Not used in California processing tomato, but additional rating provided based on efficacy in other crops.
[3] Strychnine baits are only legally allowed for gopher control.

# Appendix III: Relative Toxicities of Insecticides and Miticides to Beneficial Insects

Rating system: N = No information, L = low toxicity, M = moderate toxicity, H = high toxicity.

Honey bee ratings derived from the UC IPM *Bee Precaution Pesticide Ratings*:

I = (Highest toxicity) Do not apply or allow to drift to plants that are flowering, including weeds. Do not allow pesticide to contaminate water accessible to bees including puddles.

II = (Moderate toxicity) Do not apply or allow to drift to plants that are flowering including weeds, except when the application is made between sunset and midnight if allowed by the pesticide label and regulations. Do not allow pesticide to contaminate water accessible to bees including puddles.

III = (Lowest toxicity) No bee precaution, except when required by the pesticide label or regulations.

| Active ingredient | Example trade name | Bigeyed bug | Lacewings | Lady beetles | Minute pirate bug | Parasitic wasps | Spiders | Syrphid fly larvae | Honey bees |
|---|---|---|---|---|---|---|---|---|---|
| abamectin (spray) | Agri-Mek | L | L | L | L | M–H | H | L | I |
| acetamiprid | Assail | L–M | M–H | H | N | L | L | N | II |
| azadirachtin | Debug | L | M | M | L | M | L | N | II |
| *Bacillus thuringiensis* ssp. *aizawai* | Agree | L | L | L | L | L | L | L | II |
| *Bacillus thuringiensis* ssp. *kurstaki* | Condor | L | L | L | L | L | L | L | III |
| beta-cyfluthrin | Baythroid | H | H | H | H | H | H | H | I |
| buprofezin | Courier | M–H | L | L–M[2] | L | L | L | H | II |
| *Burkholderia* spp., strain A396 | Venerate | N | N | N | N | N | N | N | II |
| carbaryl bait | Sevin bait | L | L | L | L | L | L | L | III |
| carbaryl spray | Sevin XLR | H | H | H | H | H | H | H | I |
| chlorantraniliprole | Coragen | L | H | L | L | L–M | M | L | III |
| clothianidin | Belay | M | H | M | H | M–H | N | N | I |

| **Active ingredient** | **Example trade name** | Bigeyed bug | Lacewings | Lady beetles | Minute pirate bug | Parasitic wasps | Spiders | Syrphid fly larvae | Honey bees |
|---|---|---|---|---|---|---|---|---|---|
| cyantraniliprole | Verimark | L | H | L | L | L | L | N | I |
| diazinon | (not applicable) | H | H | H | H | H | H | H | I |
| dimethoate | (not applicable) | H | H | H | H | H | H | H | I |
| dinotefuran | Venom | L | M–H | M | L | L | N | L | I |
| emamectin benzoate | Proclaim | L | L | L | L | L | L | N | I |
| esfenvalerate | Asana | H | H | H | H | H | H | H | I |
| fenpropathrin | Danitol | M | M | H | N | H | H | H | I |
| flonicamid | Beleaf | L | L | L | L | L | L | L | III |
| flupyradifurone | Sivanto | L | L | M | L | L | L | N | II |
| imidacloprid | Admire | L–M | M–H | H | M–H | L–H[1] | L | N | I |
| indoxacarb | Avaunt | L | L | L | L | L | L | L | I |
| insecticidal soap | M-Pede | L | L | L | L | L | L | L | III |
| lambda-cyhalothrin | Warrior | H | H | H | H | H | H | H | I |
| malathion | — | H | H | H | H | H | H | H | I |
| methomyl | Lannate | H | H | H | H | H | H | H | I |
| methoxyfenozide | Intrepid | L | L | L | L | L | L | L | III |
| neem oil | Trilogy | L | L | L | L | L | L | L | III |
| novaluron | Rimon | L | L–H[2] | L | L | L | L | L | I |
| oxamyl | Vydate | H | H | H | H | H | H | H | I |
| pymetrozine | Fulfill | L | L | L | L | L | L | L | II |
| pyrethrins | PyGanic | H | H | H | H | H | H | H | I |
| pyrethroids | various trade names | H | H | H | H | H | H | H | I |
| pyriproxyfen | Knack | L | L–H[2] | H | L | L | N | N | II |
| rosemary/ peppermint oil | Ecotrol | L | L | L | L | L | L | L | III |
| spinosad bait | Seduce | L | L | L | L | L | L | L | III |
| spinosad spray | Entrust, Success | L | L | L | L | L–M | M | M–H | II |
| spinetoram | Radiant | M | M–H | M | M | M–H | N | M | II |
| sulfur | | L | L | L | L | L | L | L | III |
| thiamethoxam* | Actara, Platinum | M–H | M–H[2] | L–M | L–H[3] | M | L | L | I |
| thyme oil | Proud | L | L | L | L | L | L | L | III |

| **Active ingredient** | **Example trade name** | Bigeyed bug | Lacewings | Lady beetles | Minute pirate bug | Parasitic wasps | Spiders | Syrphid fly larvae | Honey bees |
|---|---|---|---|---|---|---|---|---|---|
| zeta-cypermethrin | Mustang | M | M | M | M | M | M | M | I |

[1] = toxicity depends on the type of application (foliar or seed/soil). For imidacloprid, foliar applications are highly toxic to parasites of tomato pests. Soil and seed treatments have low toxicity.
[2] = Higher toxicity rating applies to larvae or juveniles; lower toxicity rating applies to adults.
[3] = High toxicity in laboratory studies, variable results in different field studies.
* = Also see clothianidin, as clothianidin is a secondary compound that results from the breakdown of thiamethoxam.

# Appendix IV: Graphs of Insecticide Use in California Processing Tomato

The following graphs provide supplementary information on trends in the use of major insecticides in California processing tomato. These pesticides are used to manage significant insect pests such as thrips, beet leafhopper, or stink bugs. Several insecticides important to managing these pests are in the carbamate, organophosphate, and neonicotinoid insecticide groups, which are likely to be subject to further restrictions or cancellations in the future due to their nontarget impacts (high mammalian toxicity for organophosphates and carbamates, and high toxicity to pollinators for neonicotinoids).

Data for these figures was compiled using the California Department of Pesticide Regulation Pesticide Use Reporting data, using the most recent data available at the time this report was being compiled.

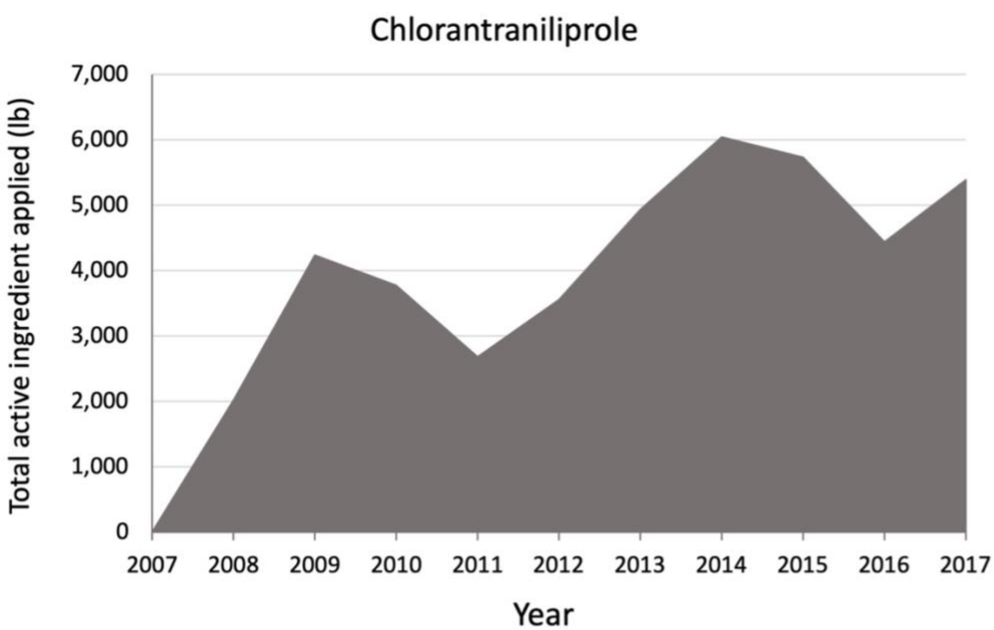


**Figure I.** Chlorantraniliprole is a systemic insecticide (though not a neonicotinoid) used to manage beet leafhopper and various caterpillar pests. Its use has largely increased between 2007 and 2017. Though this insecticide is systemic, it is largely considered to be less impactful on nontarget species than neonicotinoids.

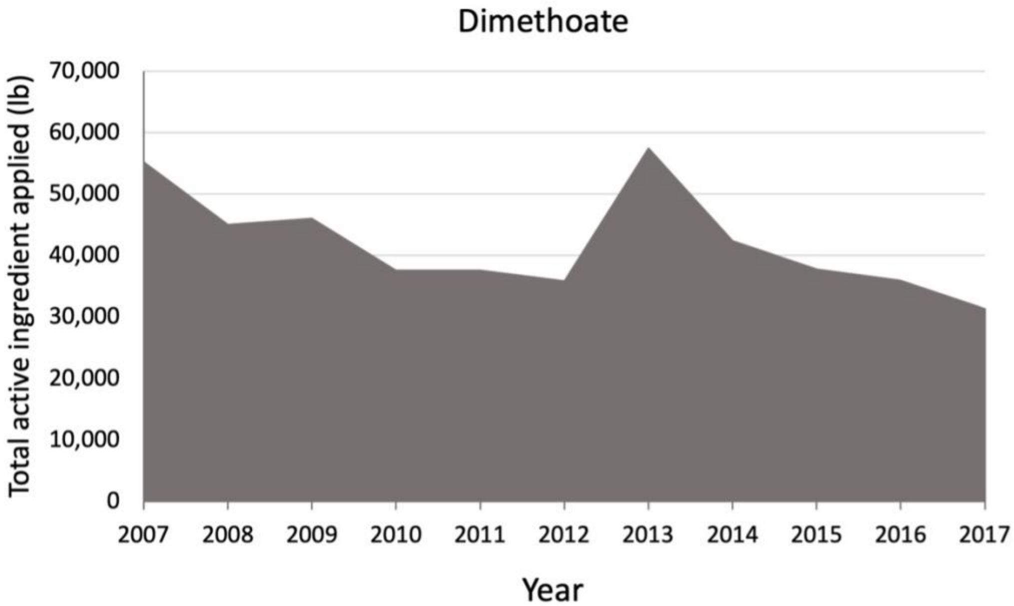


**Figure II.** Dimethoate is an organophosphate insecticide that is used to manage stink bugs and thrips. It may also be used to manage lygus bugs, though these pests are less of an issue than the latter two. Total dimethoate use has gradually decreased since 2007, though there was a small spike in its use in 2013.

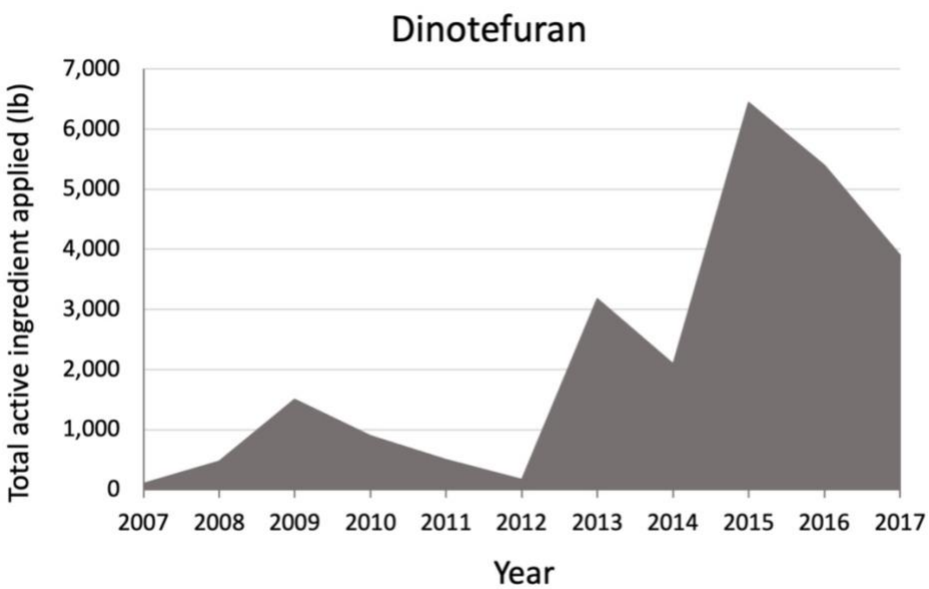


**Figure III.** Dinotefuran is a nitroguanidine neonicotinoid that is used to manage beet leafhopper and stink bugs. The total amount of dinotefuran has increased substantially, particularly after 2012. However, even with increased use, total amount of dinotefuran applied to processing tomato is much less than that of imidacloprid.

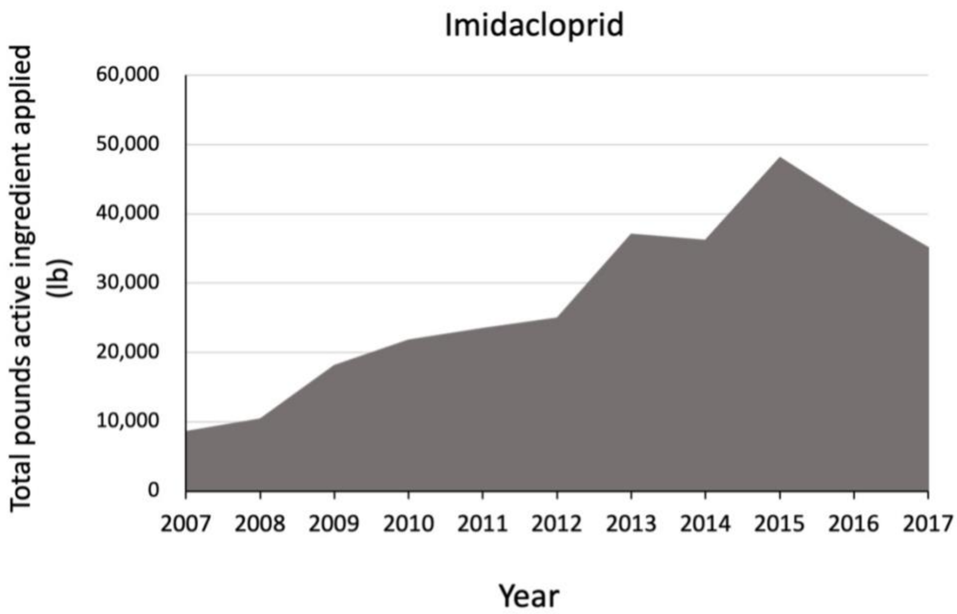


**Figure IV.** Imidacloprid is a nitroguanidine neonicotinoid that has come under intense scrutiny for its impacts on pollinators and other nontarget species. This insecticide is used to manage beet leafhopper and is also effective against lygus bugs and aphids. It has also been used to manage stink bugs in the past, although it is less effective against stink bugs. The amount of imidacloprid used in processing tomato has generally increased since 2007, though use declined slightly between 2015 and 2017.

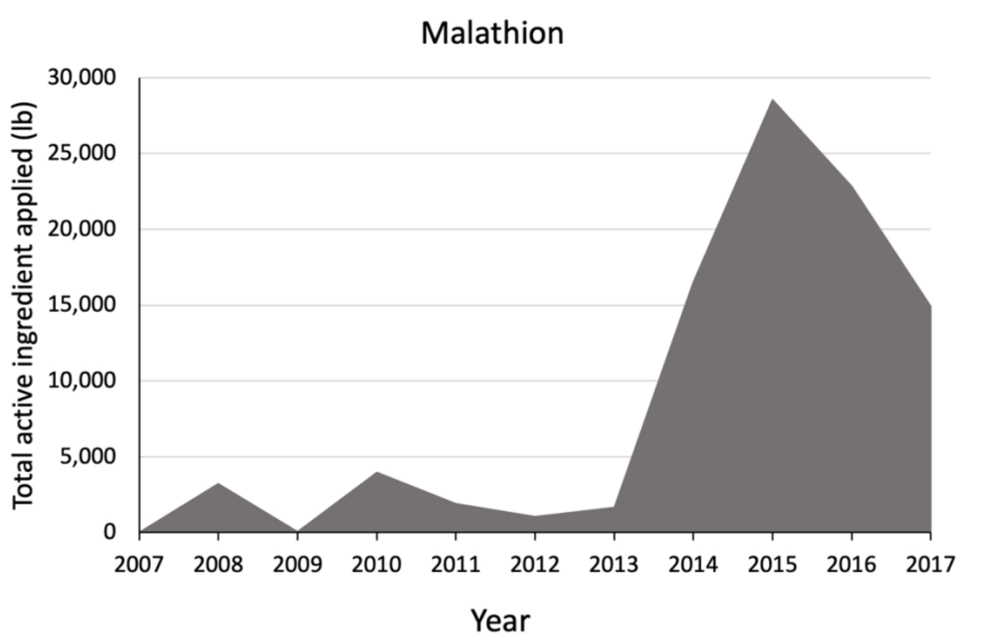


**Figure V.** The total amount of malathion applied in California processing tomato has generally increased between the years 2007 and 2017, with the greatest increases occurring after 2013 (though with some decline from 2015 to 2017). This insecticide is heavily relied upon for beet leafhopper control and prevention of *Beet curly top virus* infections. It may also be used to manage thrips.

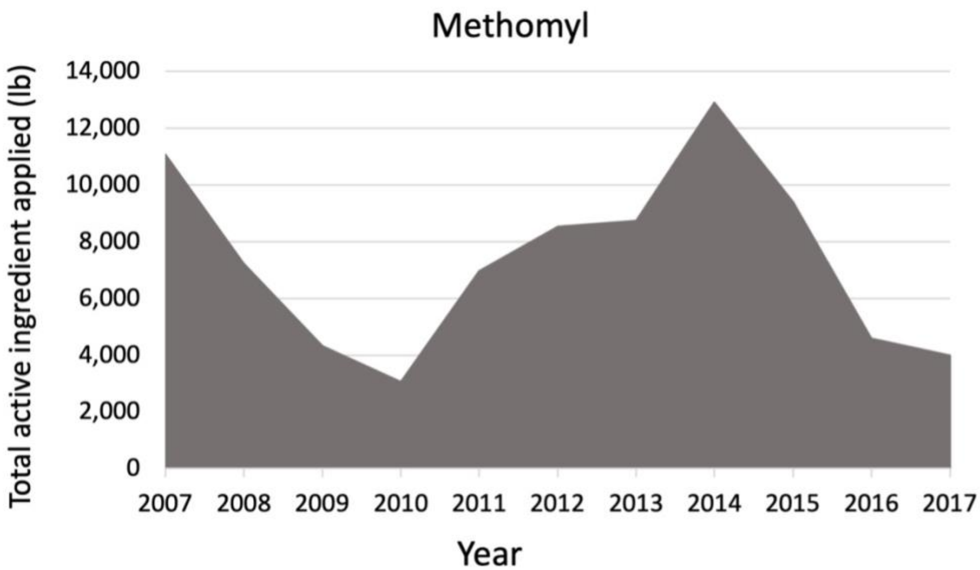


**Figure VI.** Methomyl is a carbamate insecticide that is most typically used to manage stink bugs, though it can also be used to manage caterpillar pests if high numbers of mature caterpillars are present. Total amount of methomyl applied to processing tomato each year has decreased overall between 2007 and 2017, though there was a steep rise in use between 2010 and 2014 (possibly for beet leafhopper management).

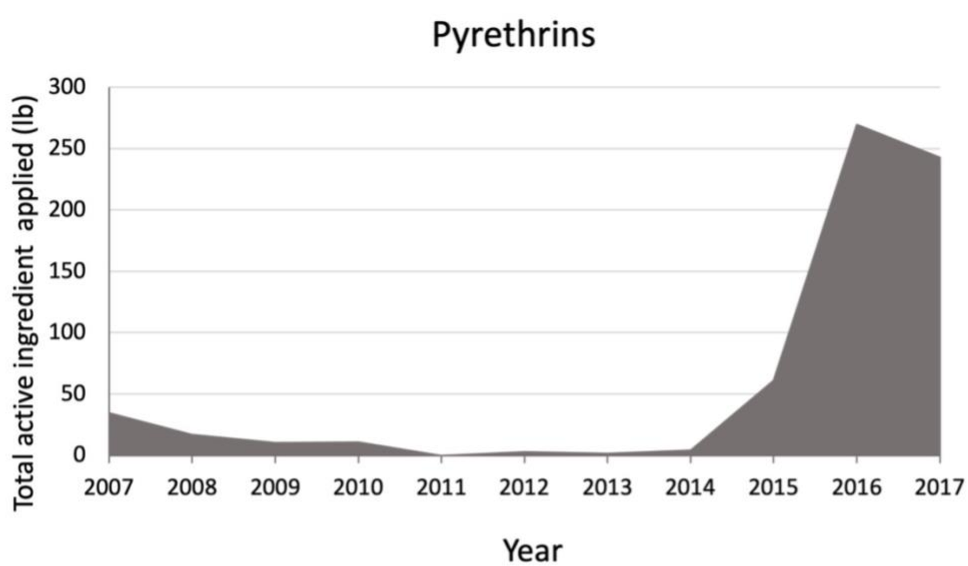


**Figure VII.** Pyrethrins are used to manage various pests (including but not limited to beet leafhopper) primarily in organic processing tomato. The amount of pyrethrins applied to processing tomato has rapidly increased since 2014, presumably due to the need to manage beet leafhopper in the southern region.

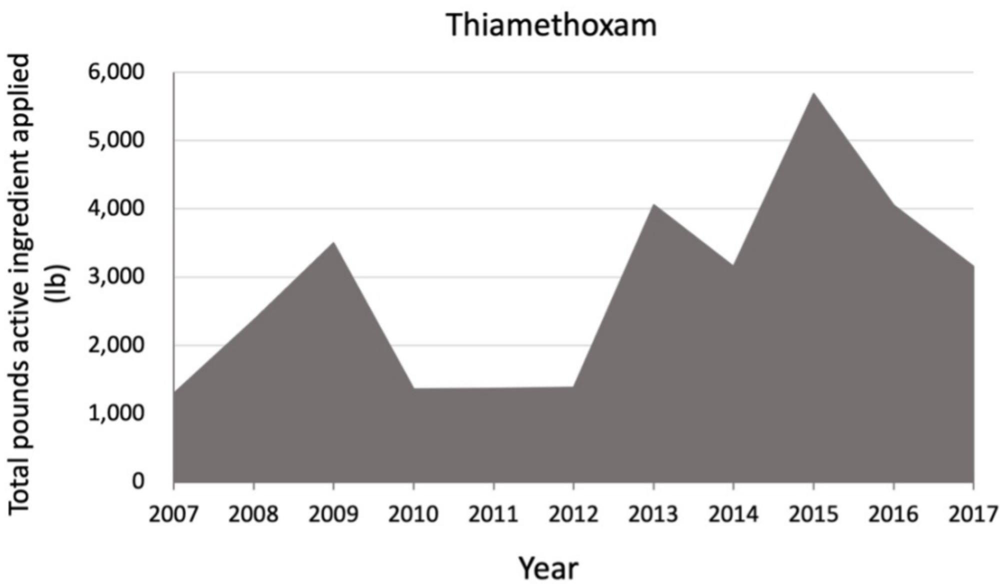


**Figure VIII.** Thiamethoxam is one of the nitroguanidine neonicotinoids identified as being particularly harmful to insect pollinators. It is primarily used to manage beet leafhopper. In addition to being a neonicotinoid itself, one of its metabolites (breakdown products) is clothianidin, which is also a neonicotinoid. Trends in amount of thiamethoxam used in California processing tomato are somewhat less apparent than those of other insecticides used in this crop, but there were clear and substantial increases in its use between the years of 2012 and 2015. Generally, much less thiamethoxam is used in processing tomato than imidacloprid.

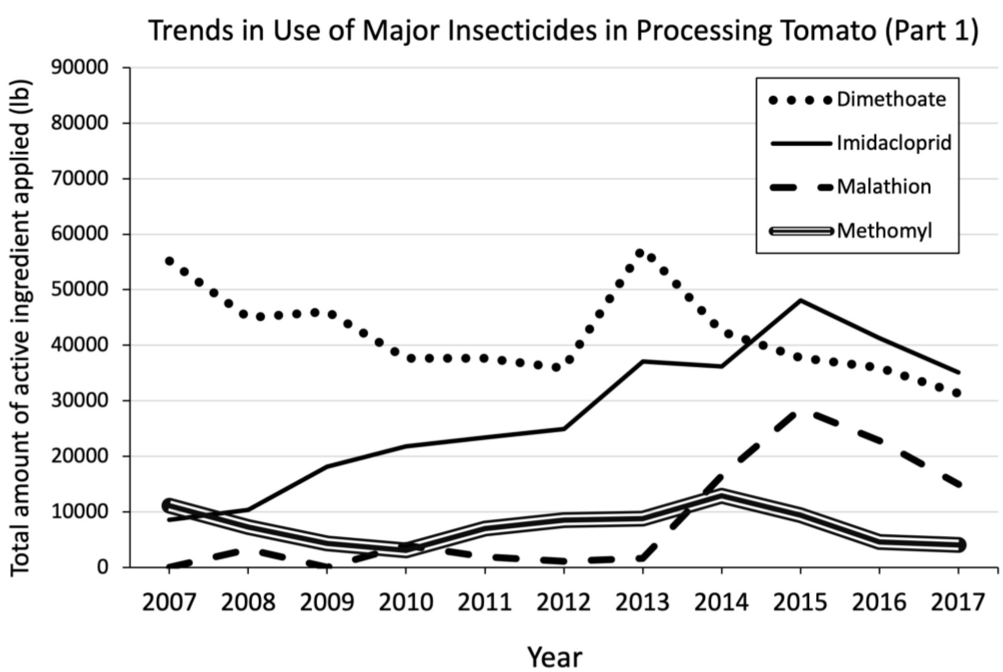


**Figure IX.** The insecticides depicted in Figures I–VIII demonstrate different trends in use for individual insecticides. However, the magnitude of use reductions and increases varies for each of these insecticides. This figure shows the insecticides from Figures I–VIII with the highest usage amounts between the years 2007 and 2017. dimethoate, imidacloprid, malathion, and methomyl. The increase in imidacloprid application appears to be the most significant from these insecticides. Imidacloprid use increased from less than 10,000 lb applied in 2007 to more than 30,000 applied in 2017 (with a peak use of almost 50,000 lb in 2015). While dimethoate use has declined, total amount applied remains high, with more than 30,000 lb applied in 2017 (and a peak of almost 60,000 lb applied in 2013). Malathion use remained relatively low (less than 5,000 lb applied per year) until after 2013. Between 2013 and 2015, the total amount of malathion applied to processing tomato per year tripled, and in 2017 nearly 15,000 lb were applied. Compared to these three insecticides, the amount of methomyl applied is substantially lower (with a maximum of less than 13,000 lb), and its trends of increasing or decreasing use is much less pronounced.

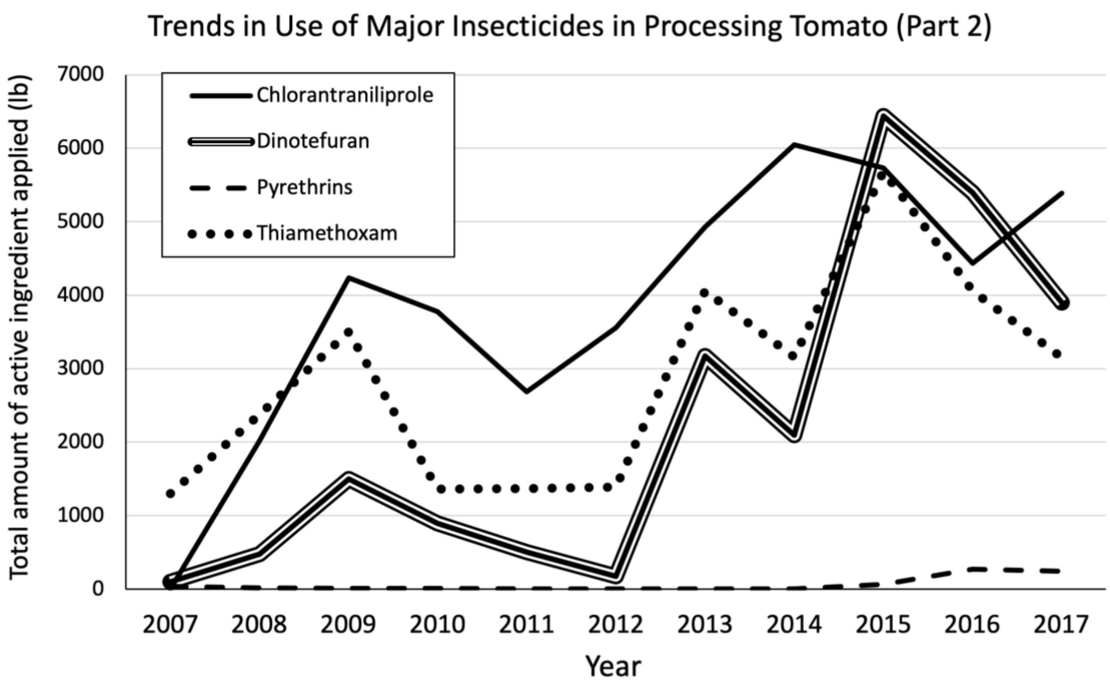


**Figure X.** This figure demonstrates the trends in use for major processing tomato insecticides that have maximum yearly use of less than 7000 lb. Though use of pyrethrins has increased from 2014 to 2017, use of pyrethrins compared to other insecticides in processing tomato remains extremely low (less than 500 lb per year). The other three insecticides shown demonstrate similar trends of increases and decreases from 2007 to 2017. Peak usage for these insecticides during this period are as follows: 1) chlorantraniliprole— maximum of 6044 lb applied in 2014, 2) dinotefuran— maximum of 6441 lb applied in 2015, 3) thiamethoxam— maximum of 5685 lb applied in 2015.

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