UC IPM Tomato

September 2014

PEST MANAGEMENT GUIDELINES FOR AGRICULTURE

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Publication 3470 • Online with photos at http://www.ipm.ucanr.edu/PMG/selectnewpest.tomatoes.html

University *of* California

Agriculture and Natural Resources • **UC Statewide Integrated Pest Management Program**

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UC PEER REVIEWED

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The UC IPM Pest Management Guidelines are available from:

- **Online:** http://www.ipm.ucanr.edu
- **UC Cooperative Extension County Offices**
- **University of California**
  ANR Communication Services
  Richmond, CA 94804
  510-665-2195; 800-994-8849

Updates: These guidelines are updated regularly. Check with your University of California Cooperative Extension Office or the UC IPM Web site for information on updates.

To be used with UC ANR Publication 3274,
Integrated Pest Management for Tomatoes, 4th edition

Tomato Year-round IPM Program

ANNUAL CHECKLIST *(Reviewed 12/12)*

These practices are recommended for a monitoring-based IPM program that reduces water quality problems related to pesticide use. Track your progress through the year using this form.

Water quality becomes impaired when pesticides move off-site and into water. Each time a pesticide application is considered, review the Pesticide Application Checklist at the bottom of this form to learn how to minimize water quality problems.

This program covers the major pests of tomatoes for processing. Details on carrying out each practice, information on additional pests, and additional copies of this form are available from the UC IPM Pest Management Guidelines: Tomatoes at http://www.ipm.ucanr.edu/PMG.

✓ **Done**	Preplanting **Special issues of concern related to water quality:** Fertilizer application, herbicide application, drift, and runoff due to rain or irrigation.
	Consider a cover crop (rather than fallowing or using vegetative filter strips) to: • Minimize rainfall runoff • Improve infiltration • Reduce erosion
	Consider a subsurface drip irrigation system or other modifications of your irrigation system to reduce run off and risk of diseases and weeds. Perform maintenance if a drip irrigation system is already installed.
	Select your field, considering cropping and pest history, and surrounding crops;check previous crop for signs of disease or soil problems that may affect tomatoes.
	If nematode galled roots were found in the previous season, consider resistant varieties, nematicides, or an alternate crop.
	Review records of weed species and numbers in the previous crop. Evaluate fallow or preplant herbicide needs.
	Take a preplant soil sample for nutrient and salinity analysis, and apply preplant fertilizer.
	Check field and surrounding land for vole and gopher activity in late fall or winter.
	Consider crop rotation for reducing pathogen, nematode and weed problems.
	Consider a preplant irrigation in the Southern San Joaquin Valley.
	Select a tomato variety, considering: • Dodder presence in previous crop (especially if previous crop was tomato or other dodder host such as alfalfa) • Prevalent pathogen problems • Nematode problems
	Use healthy, pathogen-free transplants.
	Consider tillage options before planting.
	If weather has been cool and wet and bacterial speck has been common in the field, consider delaying planting.

✓ Done	Planting to prebloom **Special issues of concern related to water quality:** Fertilizer application, herbicide sprays, fungicide application, insecticide application, drift, and runoff due to irrigation or rain.
	With transplants, take caution not to move pests from the greenhouse to the field. Before planting, visually inspect plants for diseases and insects. • Destroy plants with late blight, gray mold, sweetpotato whitefly or pinworm.
	Apply starter fertilizer at planting.
	Consider an irrigation if your location has not had adequate spring rain.
	Look for insects, seedling diseases, and blank spots **Direct-seeded:** from seedling emergence until the 2 to 3 true leaf stage **Transplants:** for several weeks after transplanting • Aphids • Cutworms • Damping-off • Darkling beetles • Flea beetles • Garden symphylans • Wireworms
	Survey and manage weeds: • Cultivate weeds along plant line. • Consider hand weeding. • Consider applying herbicides after planting based on survey information. • Keep records on a weed survey form (PDF).
	In furrow irrigated systems, consider sidedressing the crop with nitrogen at prebloom. Use a pre-sidedress soil nitrate test to help guide fertilizer applications.
	Consider applying bactericides for: • Bacterial speck—if historicallyit has been common in the field or is present now and the weather has been cool and wet, with forecasts for similar conditions. • Bacterial spot—if present and the weather has been mild and wet.
	Look for bacterial canker and manage according to the Tomato Pest Management Guidelines, especially under cool and wet conditions or in sprinkler-irrigated fields.
	Sporadic or minor pests you may see: • Alfalfa mosaic • Curly top • Rodents, including voles • Tomato spotted wilt

✓ Done	Bloom to early fruit set (up to 1-inch-diameter fruit) **Special issues of concern related to water quality:** Fertilizer application fungicide application, drift, runoff due to irrigation.
	Start monitoring for consperse stink bugs by placing stink bug pheromone traps in the field at flowering, especially in fields with a history of damage.
	Take petiole and leaf tissue samples for nutrient analysis and apply nutrients as necessary.
	Irrigate as required for plant growth.

✓ Done	Bloom to early fruit set (up to 1-inch-diameter fruit) **Special issues of concern related to water quality:** Fertilizer application fungicide application, drift, runoff due to irrigation.
	Look for diseases such as: • Corky root • Fusarium crown and root rot • Curly top • Fusarium wilt • Tomato spotted wilt • Verticillium wilt Clean equipment to reduce transfer of diseases to non-infected fields. Keep records for next year's management practices.
	Monitor weekly for signs and symptoms of powdery mildew.
	Sporadic or minor pests you may see: • Aphids (green peach and other early season aphids, potato) • Armyworms • Hornworms • Loopers • Lygus bugs • Thrips • Tomato pinworm • Tomato bug • Tomato fruitworm • Virus symptoms • Whiteflies

✓ Done	Late fruit set (1-inch fruit to first red fruit) **Special issues of concern related to water quality:** Fertilizer application fungicide application, insecticide application, drift, runoff due to irrigation.
	Use irrigation practices that will enhance fruit yield and quality.
	Take leaf samples for: • Tomato fruitworm • Potato aphid Keep records on a monitoring form (PDF).
	Sample for stink bugs by shaking vines. Treatment is not usually required for juice or paste tomatoes, otherwise treat if needed according to the Tomato Pest Management Guidelines.
	When fruit are 1 inch or more in diameter, sample fruit for: • Beet armyworm • Western yellowstriped armyworm Keep records on a monitoring form (PDF) and treat if needed according to the Tomato Pest Management Guidelines.
	Continue monitoring for leaf and stem bronzing due to russet mite.
	Watch for diseases: • Bacterial canker • Late blight • Buckeye rot Treat if needed according to the Tomato Pest Management Guidelines.
	Consider management for blackmold according to the Tomato Pest Management Guidelines.
	Look for signs and symptoms of powdery mildew.
	Sporadic or minor pests you may see: • Aphids (green peach and other early season aphids, potato) • Hornworms • Loopers • Lygus bugs • Thrips • Tomato bug • Tomato pinworm • Virus symptoms • Whiteflies

✓ Done	First red fruit (preharvest) **Special issues of concern related to water quality:** Insecticide application, fungicide application, drift, fertilizer application, runoff due to irrigation.
	Control irrigation to maintain yield and fruit quality.
	If a late harvest is planned, consider management options for: Blackmold • Powdery mildew, unless a few weeks before harvest
	Take leaf samples for: • Tomato fruitworm • Potato aphid Keep records on a monitoring form (PDF).
	Monitor fruit for armyworm damage and distinguish from fruitworm and cutworm damage. Keep records on a monitoring form (PDF) for armyworm.
	Survey for weeds just before harvest for next year's planning. Keep records on a survey form (PDF).
	Sporadic or minor pests you may see: • Cutworms • Leafminers • Tomato psyllid • Flea beetles • Lygus bugs • Whiteflies • Hornworms • Tomato pinworm

✓ Done	Harvest and postharvest
	Harvest promptly to reduce fruit rot problems such as blackmold.
	Identify pest damage in harvested fruit.
	Consider fall soil sampling for nutrients and nematodes.
	For weedy fields, especially those with perennial weeds such as field bindweed and little mallow, apply irrigation followed by contact herbicides according to the Tomato Pest Management Guidelines.
	Plan fallow season, cover crop, or overwintering crop management to reduce runoff and erosion. Deep ripping, if planned, is best done postharvest.
	Plan for next year.

✓ Done	Pesticide application checklist When planning for possible pesticide applications in an IPM program, consult the Pest Management Guidelines, and review and complete this checklist to consider practices that minimize environmental and efficacy problems.
✓	**Choose a pesticide from the Pest Management Guidelines for the target pest, considering:**
	• Impact on natural enemies and pollinators. For more information see Protecting Natural Enemies and Pollinators at http://www.ipm.ucanr.edu/mitigation/protect_beneficials.html.
	• Potential for water quality problems using the UC IPM WaterTox database.See www.ipm.ucdavis.edu/TOX/simplewatertox.html.
	• Impact on aquatic invertebrates. For more information, see *Pesticide Choice*, UC ANR Publication 8161 (PDF), http://anrcatalog.ucdavis.edu/pdf/8161.pdf.
	• Chemical mode of action, if pesticide resistance is an issue. For more information, see *Herbicide Resistance: Definition and Management Strategies*, UC ANR Publication 8012 (PDF), http://anrcatalog.ucdavis.edu/pdf/8012.pdf.
	• Endangered species that may be near your site. Find out using the Department of Pesticide Regulation's PRESCRIBE program. (http://www.cdpr.ca.gov/docs/endspec/prescint.htm)
✓	**Before an application**
	Ensure that spray equipment is properly calibrated to deliver the desired pesticide amount for optimal coverage. (See www.ipm.ucdavis.edu/training/incorporating-calibration.html)
	Use appropriate spray nozzles and pressure to minimize off-site movement of pesticides.
	Avoid spraying during these conditions to avoid off-site movement of pesticides. • Wind speed over 5 mph • Temperature inversions • Just prior to rain or irrigation (unless it is an appropriate amount, such as when incorporating a soil-applied pesticide) • At tractor speeds over 2 mph
	Identify and take special care to protect sensitive areas (for example, waterways or riparian areas) surrounding your application site.
	Review and follow labeling for pesticide handling, personal protection equipment (PPE) requirements, storage, and disposal guidelines.
	Check and follow restricted entry intervals (REI) and preharvest intervals (PHI).
✓	**After an application**
	Record application date, product used, rate, and location of application.
	Follow up to confirm that treatment was effective.

✓ Done	Pesticide application checklist
✓	**Consider water management practices that reduce pesticide movement off-site.**
	Consult relevant publications, such as *Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops*, UC ANR Publication 8403 (PDF), http://anrcatalog.ucdavis.edu/pdf/8403.pdf.
	Consult the Department of Pesticide Regulation Groundwater Protection Program (GWPA) Web site for pesticide information and mitigation measures. (http://www.cdpr.ca.gov)
	Install an irrigation recirculation or storage and reuse system. Redesign inlets into tailwater ditches to reduce erosion. (For more information, see *Reducing Runoff from Irrigated Lands: Tailwater Return Systems*, http://anrcatalog.ucdavis.edu/pdf/8225.pdf.)
	Use drip rather than sprinkler or flood irrigation.
	Limit irrigation to amount required using soil moisture monitoring and evapotranspiration (ET).
	Consider using cover crops.
	Consider vegetative filter strips or ditches. (For more information, see *Vegetative Filter Strips,* UC ANR Publication 8195 (PDF), http://anrcatalog.ucdavis.edu/pdf/8195.pdf.)
	Apply polyacrylamides in furrow and sprinkler irrigation systems to prevent off-site movement of sediments.
✓	**Consider practices that reduce air quality problems.**
	When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding fumigants and emulsifiable concentrate (EC) formulations.
	Use the Department of Pesticide Regulation calculators to determine VOC emission rates from fumigant and nonfumigant pesticides. (http://www.cdpr.ca.gov)

More information about topics mentioned on this checklist is available at the UC IPM Web site: http://www.ipm.ucanr.edu/PMG/selectnewpest.tomatoes.html.

For more about mitigating pesticide hazards, see the Mitigation pages: www.ipm.ucanr.edu/mitigation/.

General Information

(Section reviewed 12/13)

SELECTING THE FIELD (12/13)

Tomatoes planted in fields infested with tomato pests or fields with poor nutrient balance will suffer yield loss. Choose fields for tomato planting carefully, taking into account the field's cropping history.Also take into account pest problems that may originate in adjacent crops or fallow ground. Do these areas harbor pests of tomato such as root knot nematode, potato tuberworm, or problematic weeds? Many weed problems can be reduced by not planting tomatoes in fields that are severely infested with difficult weeds such as nightshades, field bindweed, nutsedge, and parasitic dodder. If this is unavoidable, treat weed infestations before planting (see SPECIAL WEED PROBLEMS).

Use the information below when selecting fields for tomato planting. Well-chosen fields can result in fewer pest problems.

ASSAY SOIL AND WATER

Identify soil type

Tomatoes can grow in a variety of soil types; however, deeploams and clay loams are preferred. Heavy clay soils require very careful water management and are generally less desirable. Sandier soils usually have higher root knot nematode populations than soils that are more loamy. Avoid fields with large sandy streaks. Major variations in soil type within a field make application of herbicides difficult because rates must be adjusted for soil type. Drip irrigation can reduce irrigation-related management problems.

Nutrient and mineral levels

Check for excessive salt and boron, and other mineral imbalances. Soil electrical conductivity (ECe), expressed as deciSiemens per meter (dS/m), is used to measure soil salinity. Values above 4 are considered high and may require soil amendments. Boron levels greater than 5 ppm can also cause crop problems. In some Sacramento and San Joaquin valley soils, magnesium levels can be high enough to cause problems with potassium uptake.

Soil pH

Tomatoes grow best at pH 6.0 to 7.5.

Herbicide residues

Specific herbicide residues may inhibit seedling growth. Perform a soil herbicide bioassay if potentially damaging herbicide carryover is suspected.

Check irrigation water

If the quality of the irrigation water is unknown, assay for pH, salinity, nitrate levels, and specific ion toxicities. Irrigation water quality is also important for drip irrigation systems, as carbonates, iron, and organic matter can cause problems with filtration and clogging.

Root knot nematodes

Assay for nematodes before planting tomatoes if they have been a problem in a previous crop. The best time to do this is in the fall when numbers are at the highest or spring before planting.

CHECK RECORDS

Agronomic information

Determine the past tomato production history including planting and harvest dates and yields. See if the field has supported successful production.

Cropping history

Identify previous crops that are known hosts of tomato pests. Determine if pests such as garden symphylans, pinworms, potato tuberworm, nematodes, Fusarium or Verticillium wilt, and dodder or other weeds that might carry over to a new tomato crop, were present.

Surrounding crops and areas

Check for cultivated crops such alfalfa, cotton, or safflower that harbor lygus bug, which damages tomato fruit. Check alfalfa for armyworms, cutworms, darkling beetles, whiteflies, and tomato pinworm. If pinworm is found, get rid of solanaceous weeds in and around the tomato field that may harbor them.

FIELD PREPARATION (12/13)

Optimal physical and chemical soil conditions result in healthy plants. Poor soils require remedial action in order to support healthy plants; this may take many years and can be expensive. Use the table below to compare tomato field requirements with the conditions of your prospective site. If there are specific site problems, you will need to determine if remediation is feasible. Proper field preparation is also essential for minimizing fertilizer and pesticide runoff.

Site problem	Remedy	Comments
Hardpan, compacted soils	• Deep ripping	Tomato grows successfully on a range of soil textures, but deep, loamy, well-drained soil with organic matter is preferred.
Sandy soils	• Irrigate more often	
Clay soils with poor aeration	• Install drainage tiles	
Uneven topography, waterlogging	• Precise field leveling appropriate for irrigation system and providing for drainage at tail end • Use of subsurface drip irrigation • Install drainage tiles	
Nutrient deficiencies (nitrogen, phosphorus, and sometimes potassium)	• Fertilize if soil tests show deficiencies	See FERTILIZATION.
Low pH (less than 6.0)	• Lime the soil	
High pH (greater than 7.5)	• Reclaim (see sodic soil below)	
Saline soil (ECe greater than 2.5 dS/m)	• Reclaim: leach excess salts below the root zone	Sites with excessive salts require major modifications that can be expensive.
Sodic soil (SAR greater than 13)	• Remediation requires adequate soil calcium to replace sodium on soil cation exchange sites. If soil is low in calcium, apply gypsum ($CaSO_4$). If soil has free lime ($CaCO_3$) apply sulfur, which over time lowers soil pH and increases calcium solubility. In addition to ample soil calcium, sufficient leaching volume (from irrigation or rain) is required to move sodium below the root zone.	Sites with excessive sodium require major modifications that can be expensive, and time consuming. Sodic soils are unsuitable for tomato production until effectively remediated.
Seed or seedling pests (e.g., symphylans)	• Plow and disc old crop, cover crop, or other plant material that can harbor pests.	Symphylans will likely persist and require chemical control.
Pathogens and nematodes	• Soil solarization, deep plowing to destroy sclerotia, fumigation, crop rotation to non-host	Resistant varieties may be available. See VARIETY SELECTION.
Weeds	• Apply preplant herbicide in fall or just before planting. • Before planting in San Joaquin Valley, preirrigate the field and cultivate germinating weeds. • Deep plow (9 to 10 inches) with a moldboard plow to reduce nightshade and nutsedge populations by burying seeds and tubers.	

VARIETY SELECTION (12/13)

Where needed, choose varieties that are resistant to prevalent pathogens and nematodes. Check with the seed developer as the final authority.

Top 50 varieties by number of loads in 2012[1]

Rank	Variety	Disease resistance[3]
1	SUN 6366	VFFNP
2	H 8504	VFFNP
3	AB 2	VFFP
4	H 5608	VFFNPSW
5	H 2401	VFFNP
6	H 9780	VFFNP
7	H 3402	VFFNP
8	H 5508	VFFNPSW
9	CXD 187	VFFNP
10	H 9663	VFFNP
11	H 4707	VFFNP
12	H 1015	VFFNP
13	APT 410	VFFNP
14	BQ 205	VFFNP
15	SUN 6368	VFFNP
16	CXD 255	VFFNP
17	UG 19406	VFFNP
18	AB 3	VFFNP
19	HYPEEL 849	VFFNP
20	NUN 6394	VFFNPSW
21	BQ 206	VFFNP
22	BQ 163	VFFNP
23	H 8004	VFFNP
24	U 373	VF
25	H 9491	VFFNP

Rank[2]	Variety	Disease resistance[3]
26	H 2601	VFFNP
27	PX 650	VFFNP
28	UG 18806	VFFNP
29	H 5701	VFFNP
30	PX 002	VFFNSW
31	BOS 67212	VFFNP
32	BOS 66509	VFFNP
33	NUN 6397	VFFN
34	H 9665	VFFNP
35	H 5003	VFFNP
36	UG 19006	VFFNP
37	CXD 282	VFFFNP
38	UG 19306	VFFNP
39	HM 7883	VFFNP
40	NUN 6385	VFFNSW
41	HYPEEL 108	VFFNP
42	HM 9905	VFFN
43	SHASTA	VF
44	AB 0311	VFFNPSW
45	HEINZ 9494	VFFNP
46	HALLEY 3155	VFF
47	BQ 204	VFFNP
48	SUN 6117	VFFN
49	NUN 6404	VFFNPSW
50	HM 7885	VFN

Unranked varieties with tomato spotted wilt resistance	
DRI 319	N 6402
DRI 320	N 6407
N 6398	

Unranked varieties with dodder tolerance	
H 9492	H 9997
H 9553	H 1100
H 9888	

Unranked varieties with Fusarium wilt Race 3 resistance	
CXD 242	AB 0306
CXD 316	PX 299
HM 4802	

KEY:

V	=	Verticillium wilt (Race 1)	P	=	bacterial speck (Race 0)
F	=	Fusarium wilt (Race 1)	N	=	root knot nematode
FF	=	Fusarium wilt (Race 1 and 2)	SW	=	tomato spotted wilt
FFF	=	Fusarium wilt (Race 1, 2, and 3)			

1 As listed by the Processing Tomato Advisory Board. For more information on varieties, see http://www.ptab.org/11032012_top50.xls.

2 Ranked by market share (loads inspected in 2012).

3 Disease/nematode resistance information compiled by E. M. Miyao from: *Tomato Variety Guides* by Timothy, Stewart & Lekos Seeds and Ag Seeds Unlimited.

CROP ROTATION (12/13)

Avoid planting tomatoes in the same field year after year. Rotatingto a nonhost crop can significantly reduce pest populations in the field. The table below provides information on nonhost crops that interrupt certain tomato-associated pathogen, nematode, and weed cycles.

For winter annual weed control, choose wheat or small grains in fall and control weeds in these crops with a suitable herbicide. Consider managing summer annual weeds by growing corn in rotation with tomato. Use selective herbicides and cultivations.

Currently, research is lacking in California about how many years tomatoes can be continuously planted in non-problematic fields with drip irrigation. Preplant applications of fumigants or fungicides chemigated through the drip system can extend continuous tomato production.

Pest type	Suggested rotation cycle in years	Nonhost crop options and other comments
Diseases		
Verticillium wilt	3	Small grains, corn
Phytophthora root rot	1	Cereals for severe infestations
Bacterial spot	1 or more	Nonsolanaceous crops
Bacterial canker	1 or more	Nonsolanaceous crops
Fusarium wilt	2 or more	Crops other than tomato
Southern blight	3	Small grains
Corky root rot	2 or more	Small grains, corn
Other pests		
Root knot nematode	—	Use resistant tomato varieties and other nonhosts
Weeds	1 or more	See SPECIAL WEED PROBLEMS
Dodder	—	Use tolerant tomato varieties or grass crops

FERTILIZATION (12/13)

Most agricultural soils in California contain sufficient potassium and micronutrients to produce a tomato crop. Moderate applications of nitrogen and phosphorus are all that are required to promote seedling growth and produce maximum yields in most fields. A few may have toxic levels of certain salts.

Preplant soil testing is the primary tool for assessing nutritional needs. Depending on need, fertilizer may be applied preplant, or any time up to first red fruit. Plant tissue testing is a useful technique to confirm the adequacy of fertilization.

Higher than required rates of nitrogen and phosphorus can be both detrimental to the crop and the environment through surface runoff into waterways and leaching into groundwater. To avoid runoff of fertilizer, take measures to reduce adverse water quality problems from runoff.

PREPLANT ACTIVITIES

Soil testing for nutrient and salinity analysis

Preplant fertilization should be based on soil test nutrient levels. For the most accurate estimation of soil nutrient availability, collect and analyze soil from the main, active rooting zone, which for tomatoes is the top foot of soil. Sample a minimum of 12 soil cores from each field; if zones of different soil texture exist within the same field, take separate samples to represent each major soil type. The following table suggests appropriate soil analysis procedures, and interpretation of laboratory results.

Commonly used laboratory procedures for soil analysis and interpretation of results.

	Element and soil test procedure				
Soil test interpretation	**Phosphorus**[1] (Olsen, bicarbonate extraction)	**Potassium** (ammonium acetate extraction)	**Zinc** (DPTA extraction)	**Soluble salts; EC** (saturated paste)	**Boron** (saturated paste)
Low	< 15 ppm	< 130 ppm	< 0.5 ppm	< 2 dS/m	< 1 ppm
Medium	15-25 ppm	130-250 ppm	0.5-1.0 ppm	2-4 dS/m	1-5 ppm
High	> 25 ppm	> 250 ppm	> 1.0 ppm	> 4 dS/m	> 5 ppm

Key: < = less than; > = greater than; dS/m = mmho/cm; ppm = parts per million; EC = electrical conductivity

[1]Method estimates the relative bioavailability of inorganic orthophosphate (PO_4-P) in soils with neutral to alkaline pH. Not appropriate for soils with pH < 6.5.

Phosphorus, potassium, and zinc

For phosphorus, potassium, and zinc a low soil test value suggests the need to fertilize; with medium soil levels, yield response to fertilizer application is possible, but not necessarily likely. At high soil test levels, yield response is unlikely. For phosphorus and zinc, fertilization is best done preplant, or as a starter solution at seeding or transplanting; potassium can be applied preplant, at sidedressing, or fertigated (injected into drip irrigation water) during the growing season. Application rates up to 150 lb P_2O_5 and 200 lb K_2O are appropriate for soils testing low in these nutrients; in fields with medium test levels, up to half the rate, 75 lb P_2O_5 and 100 lb K_2O, is justified.

Soluble salts and boron

For soluble salts (salinity) and boron, soils in the low range are desirable. As soil levels increase, the likelihood of crop damage increases; when high levels of either soluble salts or boron are present, remedial actions are justified. Actions include leaching the soil profile, sprinkling during crop establishment to create a zone of lower concentration around the seedlings or transplants, and switching to a higher quality irrigation source to prevent further buildup (high soil salinity and boron is often the result of using marginal quality irrigation water).

Available nitrogen

Preplant soil testing for available nitrogen (N) is not recommended. Samples taken in the fall are undependable because winter rain or preirrigation can leach nitrate from the root zone. Soil nitrate sampling after crop establishment is useful to guide in-season nitrogen management. However, regardless of soil NO_3-N levels, heavy preplant nitrogen fertilization is not recommended. Early season crop nitrogen requirements are modest, and the

amount of nitrogen typically contained in common phosphorus fertilizers is sufficient to maintain the crop until sidedressing or fertigation (applying fertilizers through drip irrigation) can be done.

PLANTING TO RED FRUIT STAGE ACTIVITIES

Fertilizer application at transplanting

It is common practice to apply standard phosphorous fertilizers (such as 10-34-0) in transplant drenches. To minimize the potential toxicity of these fertilizers, which are high in salts, limit the application rate to no more than 2 gallons of the concentrated fertilizer per 100 gal of transplant solution.

Fertilizer application in furrow-irrigated fields

The majority of seasonal nitrogen fertilization is typically applied in a single sidedressing. A seasonal nitrogen application of about 150 lb per acre is nearly always adequate for maximum fruit yield and quality with furrow irrigation. Factoring in nitrogen applied with phosphorous fertilizer, a single sidedress application of 100 to 120 lb nitrogen per acre is normally sufficient to finish the crop. Fields with significant residual soil NO_3-N require less sidedress nitrogen; fields with soil NO_3-N greater than 15 ppm in the top foot of soil before sidedressing generally require no more than 50 lb nitrogen per acre at sidedressing.

Use of higher seasonal nitrogen rates can be both detrimental to the environment (nitrogen-rich tailwater or drain tile effluent can stimulate algae growth in the receiving water body), and to the crop. Lush vine growth stimulated by excessive nitrogen application can require additional equipment passes to trim vines and may increase fruit rot and mold problems.

A sidedress potassium (K) application can be an effective practice in fields with limited potassium supply. Because many California soils tend to fix applied potassium over time (making it less available to the crop), a banded sidedress potassium application at 100 to 200 lb K_2O may be more effective than a preplant application.

Fertilizer application in drip-irrigated fields (fertigation)

Multiple applications of nitrogen and potassium, where necessary, are injected with irrigation beginning as early as prebloom. Concentrate fertigation during the rapid growth phase of the crop, which extends from early bloom until first red fruit. Due to the higher yield potential when using drip irrigation, seasonal nitrogen rates as high as 200 lb per acre are justified. Fields with high residual NO_3-N will require less nitrogen. Nitrogen application in excess of crop demand can result in excessive vine growth, which can increase fruit mold problems. Although fertilizer can be injected with each irrigation, fertigation more often than once per week is generally unnecessary.

NUTRIENT MONITORING

Plant tissue testing can be done to help identify any growth-limiting nutrient deficiency. Whole leaf total N/P/K analysis, the best overall measure of crop nutrient status, is most useful from early flowering through full bloom. After full bloom tissue nutrient concentration is heavily influenced by nutrient export to fruit; low tissue values may not reflect nutrient deficiency.

The table below lists nutrient sufficiency guidelines. If leaf tissue analysis suggests that the crop is nutrient deficient, supplemental fertilization should be considered. Foliar fertilization can be effective for micronutrients, but the amount of NPK fertilizer that can be safely applied is severely limited by potential crop phytotoxicity.

Whole leaf nutrient sufficiency guidelines.

	Sufficiency range by growth stage	
Nutrient	First flower	Full bloom
% N	4.6–5.2	3.5–4.5
% P	0.32–0.49	0.25–0.41
% K	2.2–3.5	1.6–3.1

N = nitrogen, P = phosphorus, K = potassium

IRRIGATION OF PROCESSING TOMATOES (12/13)

Irrigation is required in California to meet the crop water use or crop evapotranspiration (ETc) requirements of processing tomatoes. Components of ETc are evaporation of water from the soil and transpiration of water from plant leaves. Seasonal amounts of ETc mainly depend on climatic conditions, planting time, and crop season length. The average seasonal ETc of processing tomatoes in California is 25 inches. However, measured seasonal ETc amounts have ranged from 21 to 30 inches of water, depending on site-specific field conditions.

Buried drip has replaced furrow irrigation as the most common irrigation method for processing tomatoes. Sprinkle irrigation is commonly used to establish seeded or transplanted stands and is sometimes used for marginal soils or in regions with high water tables.

ESTIMATING ETc

Adequate irrigation facilitates rapid canopy growth and avoids plant stress as well as root rot problems caused by excessive wetting of the soil. To determine the amount of water needed and when to apply it, calculate the ETc (crop water use) between irrigations with the following equation, where Kc is the crop coefficient and ETo is the reference crop evapotranspiration: ETc =Kc x ETo.

The crop coefficient (Kc) of tomatoes depends on the canopy size and increases as the canopy coverage increases. Information on the reference crop evapotranspiration (ETo) can be obtained from the California Irrigation Management Information System (CIMIS) at the web site http://www.cimis.water.ca.gov/cimis/ for many areas of California. ETo is provided in daily, real-time, or monthly average values.

IRRIGATION INTERVALS

Irrigate often enough so that the soil moisture depletion between irrigations does not reduce crop yield. A major factor in determining the allowable soil moisture depletions is soil texture; clay loam soils hold more water than do sandy loams and, therefore, may have longer intervals between irrigations.

Use caution in applying generalized guidelines for allowable soil moisture depletions. For example, with furrow irrigation, experience shows that cracked clay loam soils can cause *Phytophthora* problems in processing tomatoes because water can flow through cracks into the bed and saturate the soil near the middle of the bed. To reduce soil cracking, some furrow irrigators irrigate as frequently as every 3 to 5 days – an approach that requires reduced amounts of water per irrigation.

Another factor influencing irrigation intervals is whether the field is well-drained or has a shallow water table. In the Sacramento Valley where good quality, shallow groundwater exists, crop use of this groundwater can be substantial, and the crop may require fewer irrigations with less water applied per irrigation as compared to fields that are well drained. In the San Joaquin Valley where some areas have shallow, saline groundwater, try to minimize the use of groundwater by the crop. This is usually easiest to achieve with high-frequency drip irrigation, whereas it is usually not possible with low-frequency furrow or sprinkle irrigation. Drip irrigate at least two to three times per week, except under certain saline groundwater conditions where daily drip irrigations are recommended.

CALCULATING THE IRRIGATION TIME

Irrigation time is the hours required to apply the desired amount of water in a field. Calculating irrigation times for sprinkle or drip irrigation is relatively easy using the following equation where T is the hours of irrigation needed for a block, A is the acres irrigated per block, D is the inches of water to be applied, and Q is the irrigation system flow rate in gallons per minute for the block being irrigated: T = 449 x A x D/Q.

Values for D include the ETc between irrigations divided by an amount to account for the irrigation efficiency (IE), or D = ETc/IE. It is recommended that an IE of 0.85 be used for drip irrigation systems and an IE of 0.75 be used for sprinkler systems. It is important to note that values used for Q are not the tape flow rates (e.g., 0.35 gallons per hour), but rather the total gallons per minute being used to irrigate the size of block as specified in A.

Determining the irrigation time for furrow irrigation is more complicated than the other two methods of irrigation and involves factors that cannot be easily measured under field conditions. The irrigation time includes the time required for water to reach the end of the furrow, commonly called the advance time, and the time required for the desired amount of water to infiltrate along the lower end of the field. The factors affecting the

advance and infiltration times are difficult or impossible to measure in a field, so the best approach to determine irrigation time for furrow irrigation is one of trial-and-error.

Because of the advance time, more water can infiltrate along the upper part of the field than along the lower part. Many growers use furrow lengthsof 600 to 800 feet to reduce differences in infiltrated water along the furrow length. In addition, the irrigation system needs to be managed so that the water flow to the end of the field is rapid enough to reduce the differences in infiltrated water along the furrow length. One approach is to use a high rate of water inflow during the initial phase of irrigation to reduce the advance time and then to reduce the inflow rate to decrease problems with surface runoff.

MONITORING SOIL MOISTURE

Because of uncertainty in managing irrigation systems (particularly furrow irrigation),monitoring soil moisture is helpful in determining soil moisture status. Many sensors are available for monitoring soil moisture; these sensors range from inexpensive and easy-to-use to expensive and difficult to install. A popular sensor used by many irrigators is the Watermark electrical resistance block (Irrometer, Inc., Riverside, CA). It is easy to install, read, and requires no maintenance. The readout meter used with this blockprovides readings of soil moisture tension, which is the tenacity at which water is retained by the soil. The drier the soil, the higher the soil moisture tension.

IRRIGATING THE CROP

Preplant

Preplant sprinkle irrigation of about 6 inches is common in areas such as the southern San Joaquin Valley where winter rainfall frequently is insufficient to replenish the soil moisture content in the 3- to 4-foot soil profile. In areas where rainfall is sufficient, such as the Sacramento Valley, preplant irrigations are not applied. Preplant irrigations may also be used for leaching of salts in the salt-affected soil of the San Joaquin Valley.

Planting to prebloom

During this growth stage, ETc is small and consists mostly of evaporation from the soil. After sprinkler irrigation or rainfall, daily ETc may be relatively high (0.15 inches per day) because of the wet soil surface, but once the soil surface dries, the ETc decreases to about 0.05 inches per day until about 40 days after planting.

Drip irrigation can be used for stand establishment of transplanted tomatoes. Sprinkler irrigation is often used for direct-seeded tomatoes initially to germinate the crop and may continue through the early seedling growth stage before switching to furrow irrigation.

Bloom to early fruit set

The crop canopy grows rapidly during the period from bloom to early fruit set. Crop water use is small at the beginning of this growth stage but increases with time to near-maximum water use.

Late fruit set to first color/20% color

During this mid-season growth stage, crop water use, which primarily consists of transpiration, is at its maximum. Crop evapotranspiration (ETc) rates remain high, generally between 0.3 and 0.35 inches per day. The crop canopy and plant height are also at their maximum, and irrigation water management is focused on enhancing fruit development until the first sign of fruit color (excluding fruit damaged by insects or blossom end rot). At this point, the focus of irrigation management shifts from minimizing crop water stress to maximizing yield factors as described in the next section.

Red fruit/preharvest

During the period of color development, ETc decreases. Use irrigation water management practices to improve the soluble solids of the fruit while minimizing yield reductions. Maintaining the canopy coverage to protect fruit from sunburn is also desirable.

For sprinkle, furrow, and surface drip irrigation, the timing of the last irrigation should provide adequate drying of the soil before harvest by cutting off the irrigations. For subsurface drip irrigation, irrigation applications should be cut back to improve the solids content. However, irrigations can continue up to nearly the harvest time for drip irrigation systems with buried mainlines, submains, and manifolds.

With furrow or sprinkler irrigation, growers have found that cutting off irrigation 3 to 4 weeks before harvest usually achieves these goals, but this general guideline should be modified to fit specific field conditions. Studies

indicate that determining the soluble solids content of a representative sample of 15 to 20 early ripening fruit can provide an indication of the need for an earlier irrigation reduction or cutoff (Johnstone et al., 2005). If the fruit sample is considerably below the target soluble solids content for that variety, an earlier irrigation cutoff might be required; if the soluble solids content is high, then the date of irrigation cutoff can be based solely on the need to dry the field for harvest. For maintenance of the plant canopy, irrigation cutoff in coarse-textured soil should be closer to harvest than in fine-textured soil, based on the difference in available water storage.

Postharvest
Fields are generally not irrigated after harvest. In some cases, a sprinkle irrigation might occur after the beds are listed for the next crop season for weed control.

MEASURES TO REDUCE ADVERSE WATER QUALITY PROBLEMS

There is increasing concern about chemicals moving in surface runoff from irrigated fields and the impact on water quality in rivers, sloughs, and creeks. Chemicals of concern include both pesticides and nutrients. Some of thesechemicals, such as organophosphates and nitrogen, are water soluble while others, such as pyrethroids and phosphorus, are less water soluble but strongly adhere to soil particles. The measures used to reduce adverse water quality effects from surface runoff will depend to some degree on the nature of the chemicals of concern.

Water-soluble chemicals
Where water soluble chemicals (organophosphates, nitrogen) are used and their concentrations in the runoff are toxic, surface runoff must be prevented from leaving the farm using one of several approaches:

- For a given single field, a recirculation system can be used to collect the surface runoff in a small reservoir at the lower end of the field and then recirculate the water back onto the field being irrigated. The recirculated water should be used to irrigate another area of the field in order to infiltrate the runoff into the untreated soil. Simply recirculating the runoff into the same irrigation set that generated the runoff will only temporarily store the water on the field and eventually result in an increased rate of runoff. Using a recirculation system requires a tailwater pond with enough volume to store the surface runoff from an irrigation set.
- For farms with multiple adjacent fields, a storage and reuse system can be used to store all of the surface runoff from a field in a reservoir and then use the water to irrigate another field at an appropriate time. In order for this approach to work effectively the farm must have multiple fields close together, a relatively large reservoir, and a distribution system that can convey surface runoff to the storage reservoir and then back out to other fields for irrigation.
- Convert to subsurface drip irrigation. This irrigation method eliminates surface runoff if no substantial rainfall occurs.

Soil-adsorbed chemicals
Use a different approach for chemicals (pyrethroids and phosphorus) that are not water soluble but instead are strongly attached (adsorbed) to soil particles; erosion during irrigation is the main source of pollution from these chemicals. For furrow-irrigated fields, erosion occurs along the field length; however, significant erosion occurs as the water flows from the furrow into the tailwater ditch because the bottom of the tailwater ditch is lower than the bottom of the furrow. One study in Idaho shows this erosion to contribute to nearly 50% of the total sediment load leaving a field (Carter and Berg, 1983). Where sediments leaving tomato fields are contributing to water quality problems, take measures to reduce the sediment load of the surface runoff. Options available for reducing the sediment load include:

- Reducing furrow inflow rates after the water has reached the end of the field or early cutoff of irrigation water.
- Redesigning inlets into tailwater ditches to reduce erosion of the last 5 to 10 feet of the furrow. See *Reducing Runoff from Irrigated Lands: Tailwater Return Systems*, UC ANR publication 8225 at http://anrcatalog.ucdavis.edu/pdf/8225.pdf.
- Lining tailwater ditches. In some areas, erosion in the tailwater ditch has contributed to the sediment load leaving a field. Lining the ditch with synthetic liners coupled with a redesigned inlet from the furrow would reduce the erosion.
- Injecting polyacrylamides (PAM), which causes fine soil particles suspended in water to flocculate and settle out of the water, into the surface runoff. Methods of applying PAM are injecting an emulsified PAM solution directly into the irrigation water, injecting a stock solution of PAM into the irrigation water, or placingPAM granules or tablets in the furrow. The stock solution consists of dissolving PAM granules in water. Applying PAM directly into the irrigation water has the potential of reducing the suspended sediment load to nearly

zero. Additional research is neededon applying PAM using granules or tablets. Injecting PAM into the irrigation water is probably the easiest measure for growers to implement and is the most effective measure for reducing sediment in the surface runoff.

- Using sediment basins to allow sediments to settle out of the water. The basins should be large enough to allow sufficient time for particles to settle out. See *Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops,* UC ANR publication 8403, for details on construction and use. Questions remain about the ability of sediment basins to remove the clay particles to which the chemicals of concern are attached. Injection of PAM into the surface runoff before it reaches the basin may be needed to remove these clay particles.
- Allowing grass to grow in drainage ditches or tailwater ditches to reduce the speed of irrigation outflow.
- Using recirculation systems or storage and reuse systems to prevent the runoff from leaving the field.
- Converting to subsurface drip irrigation.

REFERENCES

Carter, D. L. and R.D. Berg. 1983. A buried pipe system for controlling erosion and sediment loss on irrigated land. *Soil Science Society of American Journal* 47(4): 749-752.

Johnstone, P.R., T. K. Hartz, M. LeStrange, J. J. Nunez, and E. M. Miyao. 2005. Managing fruit soluble solids with late-season deficit irrigation in drip-irrigated processing tomato production. *HortScience* 40(6): 1857-1861.

MONITORING POTATO APHID AND TOMATO FRUITWORM (12/13)

Start sampling for potato aphids 6 to 8 weeks before harvest and continue for 4 weeks. Start sampling for fruitworm eggs after adults are trapped in pheromone traps in late July or early August and continue through harvest.

HOW TO MONITOR

(View photos online of potato aphids and fruitworm eggs)

1. Pick the leaf below the highest open flower on 30 plants selected at random throughout the field. Use these leaves to monitor both potato aphid and fruitworms.
2. Record presence or absence of potato aphid on each leaf. Also note natural enemies.
3. Record observations on a monitoring form (*available online*).
4. Count fruitworm eggs on each leaf.
   - If less than 3 eggs are found, stop sampling.
   - If 3 or more eggs are found in a 30-leaf sample, sample 30 more leaves.

   Additional 30-leaf sample:
   - If less than 5 eggs are found in the second 30-leaf sample, stop sampling.
   - If 5 or more eggs are found in the second 30-leaf sample, assess egg parasitism to see if treatment is warranted.
5. If warranted, assess egg parasitism for fruitworm by counting the number of black (parasitized) eggs and compare them to the number of white, gray, and brown eggs in the table below (eggs darken naturally before hatching). If no black eggs are observed, hold the leaves and assess them 48 hours later to see if the eggs turn black from parasitism.
6. Treat if monitoring shows that thresholds have been exceeded as outlined below. The letter "T" indicates the ratio of black to white fruitworm eggs at which treatment is recommended.

TREATMENT THRESHOLDS

Tomato fruitworm									**Potato aphids**
No. of black eggs	**Number of white eggs**								• If 50% of leaves are infested, treatment may be warranted. • If the proportion of mummies is increasing or predators appear to be gaining control, and aphid populations are not yet damaging, avoid sprays that will disrupt these natural enemies.
	4-8	9	10	11	12	13	14	15	
0	T	T	T	T	T	T	T	T	
1		T	T	T	T	T	T	T	
2				T	T	T	T	T	
3					T	T	T	T	
4						T	T	T	
5						T	T	T	
6						T	T	T	
7							T	T	
8							T	T	
9								T	
10								T	

RELATIVE TOXICITIES OF INSECTICIDES AND MITICIDES USED IN TOMATOES TO NATURAL ENEMIES AND HONEY BEES (12/13)

Common name (example trade name)	Mode of action[1]	Selectivity[2] (affected groups)	General predators[3]	Parasites[3]	Honey bees[4]	Duration of impact to natural enemies[5]
abamectin (Agri-Mek)	6	moderate (mites, leafminers)	L	M/H	II	moderate to affected insects
acetamiprid (Assail)	4A	moderate (sucking insects, larvae)	—[6]	—	III	moderate
Bacillus thuringiensis ssp. aizawai	11A	narrow (caterpillars)	L	L	IV	short
Bacillus thuringiensis ssp. kurstaki	11A	narrow (caterpillars)	L	L	IV	short
beta-cyfluthrin (Baythroid)	3A	broad (insects, mites)	H	H	I	moderate
bifenthrin (Capture)	3A	broad (jnsects, mites)	H	H	I–III[9]	long
buprofezin (Courier)	16	narrow (sucking insects, beetles)	H[7]	L	IV	long
carbaryl (Sevin XLR Plus)	1A	broad (insects, mites)	H	H	II	long
carbaryl (Sevin bait)	1A	narrow (cutworms, armyworms, grasshoppers, etc.)	L	L	IV	short
chlorantraniliprole (Coragen)	28	narrow (primarily caterpillars)	L	L/M	IV	short
chlothianidin (Belay)	4A	Lygus bugs, aphids	L	L	IV	short
diazinon–granular	1B	narrow(soil insects, symphylans)	L	L	IV	short
dimethoate	1B	broad (insects, mites)	H	H	I	long
dinotefuran (Venom)	4A	narrow (sucking insects)	L	—	—	—
emamectin benzoate (Proclaim)	6	narrow (caterpillars)	—	—	III	—
endosulfan (Thionex)	2A	broad (insects, mites)	M	M	II	moderate
esfenvalerate (Asana)	3A	broad (insect, mites)	M	H	I	moderate
fenpropathrin (Danitol)	3A	broad (insects, mites)	H	H	I	—
flonicamid (Beleaf)	9C	narrow (plant bugs, fleahopper, aphids)	L	L	IV	short
flubendiamide (Belt)	28	—	L	L/M	I	short
imidacloprid, systemic (Admire Pro)	4A	narrow (sucking insects)	L	—	II	—
imidacloprid, foliar (various)	4A	narrow (sucking insects)	—	H	II	short to moderate
indoxacarb (Avaunt)	22A	narrow (caterpillars)	L	L	I	moderate
insecticidal soap (M-Pede)	—	broad (insects)	M	M	IV	short to none
kaolin clay (Surround)	—	broad (insects, mites)	M	—	IV	—
lambda-cyhalothrin (Warrior)	3A	broad (plant bugs, beetles, caterpillars)	H	H	I	moderate
malathion	1B	broad (insects)	H	H	II	moderate
methomyl (Lannate)	1A	broad (insects)	H	H	III	moderate
methoxyfenozide (Intrepid)	18	narrow (caterpillars)	L	L	IV	none
novaluron (Rimon)	15	narrow (caterpillars)	L	—	I	short
oxamyl (Vydate)	1A	broad (insects, mites)	H	H	III	moderate
permethrin (Pounce, Ambush)	3A	broad (insects, mites)	H	H	I	long
pymetrozine (Fulfill)	9B	narrow (aphids)	L	L	III	short
pyriproxyfen (Knack)	7C	narrow (aphids, whiteflies)	H[7]	L	IV	short
rosemary + peppermint oils (Ecotrol)	—	broad (exposed insects, mites)	L	L	IV	—
spinetoram (Radiant)	5	narrow (caterpillars, thrips, whiteflies, aphids, scales, leafminers)	M[10]	M/H	III	moderate[11]
spinosad (Entrust, Success)	5	narrow (caterpillars, whiteflies, thrips, aphids, leafminers, scales)	M[8]	L/M	III	short
spiromesifen (Oberon)	23	narrow (psyllids, mites, whiteflies)	—	—	—	—
spirotetramat (Movento)	23	narrow (aphids, scale, psyllids, whiteflies)	L	L	—	short

(continued next page)

Common name (example trade name)	Mode of action[1]	Selectivity[2] (affected groups)	General predators[3]	Parasites[3]	Honey bees[4]	Duration of impact to natural enemies[5]
sulfur	—	narrow (mites and thrips)	M	H	IV	short
thiamethoxam, foliar (Actara)	4A	narrow (sucking insects)	M/H	M/H	I	moderate
thiamethoxam, systemic (Plantinum)	4A	narrow (sucking insects)	—	M	I	moderate
thyme oil	—	broad (exposed insects, mites)	L	L	IV	—
zeta-cypermethrin (Mustang Max)	3A	broad (insects, mites)	M	M	I	moderate

H = high M = moderate L = low — = no information

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

2 Selectivity: broad means it affects most groups of insects and mites; narrow means it affects only a few specific groups.

3 Toxicities are averages of reported effects and should be used only as a general guide. Actual toxicity of a specific chemical depends on the species of predator or parasite, environmental conditions, and application rate.

4 Ratings are as follows: I-Do not apply to blooming plants; II-Apply only during late evening; III-Apply only during late evening, night, or early morning; and IV-Apply at any time with reasonable safety to bees. For more information, see *How to Reduce Bee Poisoning From Pesticides*, Pacific Northwest Extension Publication PNW591.

5 Duration: *short* means hours to days; *moderate* means days to 2 weeks; and *long* means many weeks or months.

6 May cause flare-ups of spider mite populations.

7 Kills lady beetles.

8 Toxic against some natural enemies (predatory thrips, syrphid fly and lacewing larvae, beetles) when sprayed and up to 5 to 7 days after, expecially for syrphid fly larvae.

9 If rate is less than 0.04 lb a.i./acre, rating is III; if 0.04 lb a.i./acre, rating is II; if 0.06 lb a.i./acre, rating is I.

10 Toxic against some natural enemies (predatory thrips, syrphid fly and lacewing larvae, beetles) when sprayed and up to 5 to 7 days after, especially for syrphid fly larvae.

11 Residual is moderate if solution is between pH of 7 to 8.

Acknowledgements: This table was compiled based on research data and experience of University of California scientists who work on a variety of crops and contribute to the Pest Management Guideline database, and from Flint, M. L. and S. H. Dreistadt. 1998. *Natural Enemies Handbook: An Illustrated Guide to Biological Pest Control*, UC ANR Publication 3386.

GENERAL PROPERTIES OF FUNGICIDES USED IN TOMATOES (12/13)

Common name (example trade name)	Chemical class (FRAC No.)[1]	Activity	Mode of action	Resistance potential
azoxystrobin (Quadris)	QoI[2] (11)	contact, systemic	single-site	high
azoxystrobin + difenoconazole (Quadris Top)	QoI[2] + DMI[3]-triazole (11 + 3)	contact, systemic	single-site + single site	low
Bacillus pumilus (Sonata)	biological (—)	contact	multi-site	low
Bacillus subtilis (Serenade)	biological (—)	contact	multi-site	low
chlorothalonil (Bravo)	chloronitrile (M5)	contact	multi-site	low
copper	inorganic (M1)	contact	multi-site	low
dimethomorph (Zampro)	cinnamic acid (40)	systemic	—	medium
famoxadone + cymoxanil (Tanos)	QoI[2] + cyanoacetamide-oximes (11 + 27)	systemic	multi-site	low
fluxapyroxad + pyraclostrobin (Priaxor)	SDHI[4] + QoI[2] (7 + 11)	systemic	single-site	medium
mancozeb (Dithane)	dithiocarbamate (M3)	contact	multi-site	low
mefenoxam (Ridomil Gold)	phenylamide (4)	systemic	single-site	high
myclobutanil (Rally)	DMI[3]-triazole (3)	systemic (local)	single-site	high
penthiopyrad (Fontelis)	SDHI[4] (7)	systemic (local)	single-site	high
pyraclostrobin (Cabrio)	QoI[2] (11)	systemic	single-site	medium
sulfur	inorganic (M2)	contact	multi-site	low
trifloxystrobin (Flint)	QoI[2] (11)	contact and systemic (local)	single-site	high

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, seehttp://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

2 QoI = quinone outside inhibitor (strobilurin)

3 DMI = demethylation (sterol) inhibitor

4 SDHI = succinate dehydrogenase inhibitor

— = not known

Insects and Mites

(Section reviewed 12/13)

BEET ARMYWORM (12/13)

Scientific Name: *Spodoptera exigua*

DESCRIPTION OF THE PEST

Beet armyworms are a widespread pest in California found in tomato fields every year. In some areas beet armyworm may be the most important caterpillar attacking tomato.

Eggs are laid on leaves in clusters covered with hairlike scales left by the female moth; there may be more than 100 eggs per cluster, but usually there are fewer. Newly hatched larvae feed together on foliage near the egg cluster and gradually disperse as they grow. Older larvae feed on leaves and fruit. Larvae usually are dull green with many fine, wavy, light-colored stripes down the back and a broader stripe along each side; they usually have a dark spot on the side of the thorax above the second true leg. The color varies, however, and the spot is absent in a proportion of some populations. The pupa is similar to that of the tomato fruitworm; it pupates in a depression made on or pocket just below the soil surface. The adult moth is mottled gray and brown with a wingspan of about 1 inch. The life cycle takes about a month in warm weather, and there are three to five generations a year.

DAMAGE

Beet armyworm attacks both foliage and fruit, creating single or closely grouped circular or irregular holes. In processing tomatoes, fruit feeding is often shallow and superficial as most wounds eventually dry. Little loss would result from feeding damage when the processing pack is for paste or juice uses. However, loss is more significant when decay organisms directly enter wounds and rot the fruit, or if feces or the caterpillar remain in the fruit. Damage is problematic for whole pack or diced uses. Check with theprocessor for acceptable levels of armyworm-scarred fruit. In fresh market tomatoes, the presence of such holes results in unmarketable fruit. The caterpillars occasionally develop inside the fruit, causing damage similar to that of the tomato fruitworm, and may feed on floral buds causing buds to abort.

MANAGEMENT

Beet armyworms are sometimes kept under control by natural enemies and a polyhedrosis virus. Use the UC fruit sampling procedure below to determine need for treatment.

Biological Control

A nuclear polyhedrosis virus often reduces populations in fall and winter. *Hyposoter exiguae, a small wasp,* is the most important parasite of beet armyworm. General predators such as bigeyed bugs and minute pirate bugs feed on eggs.

Organically Acceptable Methods

Biological control and sprays of the Entrust formulation of spinosad and *Bacillus thuringiensis* ssp. *aizawai* are acceptable for use in an organically certified crop.

Monitoring and Treatment Decisions

Processing tomatoes

In processing tomatoes, begin sampling when fruit has reached 1 inch or more in diameter. Treatment is not necessary prior to this size as the damaged fruit will fall from the plant and yield loss will be minor. Pick at least 100 fruit at random while walking through the field, being careful not to select red fruit when the majority of fruit are green. If damaged fruit are found, determine the amount of damage present and the size and species of the worms. Count fruit as damaged if it has any hole deeper than 0.1 inch (2.5 mm), if the hole is contaminated with feces, or if any larvae are present in the fruit. The treatment threshold is 3.25% damaged fruit. A sequential sampling technique is available online to help reduce the number of samples required to reach a treatment decision.

Fresh market tomatoes

In fresh market tomatoes, begin sampling when fruit appears. Pheromone traps are useful for determining when major flights occur, but not for predicting damage. A 5-minute timed search is useful in determining the need for

treatment. On average, if one or more larvae or egg masses are found in 5 minutes, treatments may be justified. Picking large numbers of fruit each week and assessing percent damage may not be economically feasible. Ground applications provide maximum effectiveness of the pesticide.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label of the product being used.

A. CHLORANTRANILIPROLE
(Coragen) 3.5–5 fl oz 4 1
MODE-OF-ACTION **GROUP** NUMBER[1]: 28
COMMENTS: Can be applied as foliar spray or by drip chemigation. Read label for treatment intervals.

B. METHOXYFENOZIDE
(Intrepid 2F) 8–16 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 18A
COMMENTS: Low toxicity to beneficials. Apply at the beginning of egg hatch. When traps indicate moth flights have begun, sample leaves for eggs. Treat when eggs are first detected.

C. FLUBENDIAMIDE
(Belt SC) 1.5 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. SPINETORAM
(Radiant SC) 5–10 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Apply as a foliar spray.

E. SPINOSAD
(Entrust)# 1.25–2.5 fl oz 4 1
(Success) 4–8 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Use higher rate for larger worms and heavy infestations. Best control is achieved when aimed at newly hatched larvae and coverage is thorough. Less toxic to natural enemies than many other choices. For resistance management, do not apply more than 0.45 lb a.i./acre per season.

F. BACILLUS THURINGIENSIS spp. AIZAWAI#
(various products) Label rates 4 0
MODE-OF-ACTION GROUP NUMBER[1]: 11A
COMMENTS: This insecticide is most effective against newly hatched larvae, so proper treatment timing is essential. This insecticide is also somewhat effective on other worm pests.

G. NOVALURON
(Rimon 0.83EC) 9–12 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Apply at egg hatch to the second instar. Use higher rates when larvae are large or foliage canopy is tall or dense.

H. EMAMECTIN BENZOATE*
(Proclaim) 2.4–4.8 oz 12 7
MODE-OF-ACTION GROUP NUMBER[1]: 6

I. INDOXACARB
(Avaunt) 3.5 oz 12 3
MODE-OF-ACTION GROUP NUMBER[1]: 22

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
J. METHOMYL* (Lannate SP)	0.5–1 lb	48	1
MODE-OF-ACTION GROUP NUMBER[1]: 1A COMMENTS: Will also control fruitworm, yellowstriped armyworm, cutworms, and cabbage looper. Primary use of methomyl should be if older larvae, which are difficult to control with other insecticides, are present. Some resistance has been documented. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
K. ESFENVALERATE* (Asana XL)	5.8–9.6 fl oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Use only when pest numbers are high close to harvest. Some resistance has been documented. May cause outbreaks of *Liriomyza* spp. leafminers and tomato russet mite. In some areas where tomatoes are grown, resistance to this material is a problem. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
L. FENPROPATHRIN* (Danitol 2.4EC)	10.66 fl oz	24	3
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Use only when pest numbers are high close to harvest. May cause outbreaks of *Liriomyza* spp. leafminers and tomato russet mites.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours(unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent thedevelopment of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

BEET LEAFHOPPER (12/13)

Scientific Name: *Circulifer tenellus*

DESCRIPTION OF THE PEST

Adult beet leafhoppers are 0.12 inch (3 mm) in length, pale green to tan in color, and may have dark markings.

DAMAGE

While some damage is caused by nymph and adult feeding, beet leafhopper is a serious pest because it vectors *Beet curly top geminivirus*. Curly top-infected plants turn yellow and stop growing. Leaves roll upward and turn purplish. Leaves and stems become stiff. Spring plantings are the most susceptible. The insect migrates from overwintering hosts in the foothills and is mostly a problem on the west side of San Joaquin Valley.

MANAGEMENT

The California Department of Food and Agriculture surveys populations of beet leafhoppers in foothill breeding areas each year and sprays when necessary to reduce leafhopper migration into valley crops.

Insecticides applied to infested fields to control beet leafhopper and reduce the spread of the curly top pathogen may prevent some infield spread, although infected plants will not recover. In areas that are at annual risk of beet leafhopper infestations, application of a systematic insecticide may have some impact. Beet leafhopper populations are greatest in years with rainfall that promotes growth of its weed hosts in the foothills.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label of the product being used.			
A. IMIDACLOPRID (Admire Pro) MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Can be used preventively as a systemic in areas with chronic infestations. Apply as a sidedress within 4 inches on either side of plants and incorporate to a depth of 2 to 3 inches. Treat at first bloom up to 8 weeks before harvest. Apply sufficient water following application to move into the root zone of the plant. Can also be applied in drip or trickle irrigation water. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	7–10.5 fl oz	12	21
B. DINOTEFURAN (Venom) MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Apply in higher volume applications at 20 gallons/acre. Do not apply to cherry or grape tomatoes or to any variety with fruit less than 2 inches in diameter. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1–4 oz	12	1
C. THIAMETHOXAM (Actara) MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	2–3 oz	12	0
D. CARBARYL (Sevin XLR Plus) MODE-OF-ACTION GROUP NUMBER[1]: 1A COMMENTS:Will also control hornworm, fruitworm, and armyworm. Do not use if psyllids are in the field as carbamates tend to promote development of their populations. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	0.66–1.25 lb	12	3

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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CUTWORMS (12/13)

Scientific Names: Variegated cutworm: *Peridroma saucia*; Black cutworm: *Agrotis ipsilon*

DESCRIPTION OF THE PESTS

Cutworm larvae come in various colors and patterns, but always appear smooth skinned to the naked eye. Most species of cutworms reach 1 to 2 inches when fully grown. They usually curl up when disturbed. Cutworms are mainly active at night. During the day, cutworms hide in soil, under clods, or in debris at the base of plants.

DAMAGE

Early in the season cutworms may cause stand loss by cutting off seedling or recently transplanted tomato plants at the soil line. Later in the season these pests can also injure tomatoes by eating irregular holes in the surface of fruits; tomato fruit touching the ground are generally the most seriously injured.

MANAGEMENT

Destroy plant residues by tilling before planting, especially when tomatoes follow a good host crop (e.g., alfalfa or beans and cover crops that include legumes) for cutworms. Manage weeds surrounding the field before planting. Kill and till under or remove weeds as cutworms will shelter in living and dead weeds. If pupae are overwintering, only getting rid of host plants may not prevent damage. During the season, monitor fruit in combination with the beet armyworms damage sample or take a separate sample of the fruit touching the ground to detect damage.

Cultural Control

Cutworm incidence is often associated with residue of host plants remaining in the field before planting and surrounding weedy plant matter. As most cutworm species have a wide host range, tillage at least 2 weeks before planting will help destroy plant residue that could harbor larvae and pupae. Because cutworm damage is often localized within a field, replanting transplants in affected areas of a field rather than treating the whole field might be more economical.

Organically Acceptable Methods

Cultural control, *Bacillus thuringiensis*, and the Entrust formulation of spinosad are organically acceptable management tools.

Monitoring and Treatment Decisions

Treat only when the presence of cutworms is detected. Cutworms are usually localized within a field, so consider marking the areas where damage is observed and treating only those areas.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. SPINOSAD
(Entrust)# — 1.25–2.5 oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Apply when eggs first hatch to target young larvae. A stomach poison. Heavy infestations require a second application in 4 or 5 days.

B. CARBARYL
(Sevin Bait 5%) — 30–40 lb — 12 — 3
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Ground application. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
C. METHOMYL* (Lannate SP)	0.5–1 lb	48	1

MODE-OF-ACTION GROUP NUMBER[1]: 1A

COMMENTS: Use only when cutworms are detected feeding on fruit. Good coverage by ground application (preferred application method) is necessary to reach the soil surface and lower fruit in the plant canopy. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies.

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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FALSE CHINCH BUG (12/13)

Scientific Name: *Nysius raphanus*

DESCRIPTION OF THE PEST

The adult false chinch bug is a small bug, about 0.12- to 0.16-inch (3–4 mm) long. It is gray to light brown in color and looks somewhat like a small lygus bug. The false chinch bug nymph is gray with a reddish brown abdomen.

False chinch bugs can occur in high numbers on weeds adjacent to, or within, tomato fields. The eggs are laid randomly on the soil or within soil cracks near weeds. The false chinch bug spends the winter primarily in the immature stage (nymph) on weeds, especially mustards. As weeds dry in spring or are destroyed, false chinch bugs may begin mass migration through tomato fields, where they feed. Nymphs predominate during migration, but adults also may be present. Important weeds that serve as hosts include wild mustard, wild radish, shepherd's-purse, and London rocket. Mustard crops, such as canola, can also be important sources of false chinch bug migration. The most serious infestations result from spring migrations; however, fall migrations can also occur. Insect movement occurs in early morning or evening when temperatures are cool, but bugs can be seen throughout the day. False chinch bug populations are likely to build to high levels during years with high winter rainfall.

DAMAGE

False chinch bugs can be an occasionally serious problem on fresh market tomato fruits. Their feeding causes indiscernible lesions on green fruits, which later become apparent as numerous, small black spots when fruits are treated with ethylene to bring on ripeness and color. Feeding on tomato foliage can cause leaves to turn brown and drop. Seedlings or newly transplanted tomatoes can be killed by the high number of migrating bugs more commonly occurring along the field edge.

MANAGEMENT

Outbreaks of false chinch bugs are unpredictable from year to year and for various geographic locations. Monitor adjacent areas and prevent populations from migrating into tomato fields, if possible.

Cultural Control

Some control can be achieved by flaming or cultivating adjoining weedy areas, grasslands, or pastures. Frequent cultivation of infested areas may inhibit migrating populations.

Organically Acceptable Methods

Cultural controls are acceptable for use on an organically certified crop.

Monitoring and Treatment Decisions

If large numbers of false chinch bugs are present in fields, treatment may be warranted. Insecticide treatment of tomato field borders may be effective in limiting invasion of migrating false chinch bugs. Treat either in the evening or early morning when chinch bugs are active.

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A.	PERMETHRIN*			
	(Pounce 25WP)	3.2–12.8 oz	12	0
	(Ambush 25W)	3.2–12.8 oz	12	0

MODE-OF-ACTION GROUP NUMBER[1]: 3A

COMMENTS: Do not apply to cherry tomatoes or other varieties that produce fruit less than one inch in diameter. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)
B. BETA-CYFLUTHRIN* (Baythroid XL)	2.8 fl oz	12	0
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Apply to soil in a minimum of 10 gallons water/acre next to or below the transplants with standard preplant fertilizer equipment just before transplants are set out in field. A maximum of one pre-transplant application is allowed per crop season.			
C. FENPROPATHRIN* (Danitol 2.4EC)	10.66 fl oz	24	3
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
D. ESFENVALERATE* (Asana XL)	9.6 fl oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
E. ZETA-CYPERMETHRIN* (Mustang Max EW)	2.24–4 oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
F. ENDOSULFAN* (Thionex 3EC)	0.66–1.33 qt	96	4
MODE-OF-ACTION GROUP NUMBER[1]: 2A COMMENTS: Do not use after July 31, 2015.			

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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\# Acceptable for use on organically grown produce.

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FLEA BEETLES (12/13)

Scientific Name: *Epitrix hirtipennis* and others

DESCRIPTION OF THE PESTS

Flea beetle adults are from 0.06 to 0.12 inch (1.5–3 mm) long. These insects derive their name from their well-developed hind legs; when disturbed they jump like fleas. Flea beetles can overwinter on weed hosts surrounding the field, on residues of a previous tomato crop, or in the soil if the previous crop was a flea beetle host.

DAMAGE

Flea beetles are common pests of seedling tomatoes in most areas. Adult beetles chew small holes in leaves, giving them a sievelike appearance. The small, slender, white larvae feed on underground parts of the plant, but this damage is not economically significant. High populations of flea beetles feeding on plants younger than the 4- to 5-leaf stage can result in stand loss, especially under hot, windy springtime conditions when the injured plants are desiccated. Foliar damage to mature plants is not considered to be economically damaging.

On rare occasions, flea beetles may feed directly on ripe fruit, just below the calyx. This damage resembles feeding by young tomato fruitworm, *Heliocoverpa zea*, or by tomato pinworm, *Keiferia lycopersicella*, and is usually seen only in very late-season plantings where leaves are senescing as a result of maturity, lack of water, or powdery mildew. Damage to fruit has caused it to be rated offgrade.

MANAGEMENT

Monitor seedling tomatoes for flea beetles, especially if the field was previously planted to tomatoes. A single treatment is generally adequate for damaging populations.

Cultural Control

Research has shown that seedling damage is significantly higher in fields previously planted to tomatoes than to crops such as wheat or sunflowers. This indicates that an overwintering population might exist; if possible, rotate tomatoes with a nonhost crop. In fields not previously planted to tomatoes, flea beetle infestations are usually locatedat field borders. Replanting rows near borders that have been heavily damaged is an option.

Late-season fruit damage may be avoided by maintaining a healthy plant canopy.

Organically Acceptable Methods

Crop rotation with a nonhost crop to reduce resident fields populations and sprays of pyrethrin are organically acceptable methods for managing these pests.

Monitoring and Treatment Decisions

Monitor fields for flea beetles soon after transplanting or after the plants emerge. Fields previously planted to tomatoes should be monitored carefully. Treat for flea beetles when small holes are observed on new transplants or on seedlings in seeded fields. In general, damage to seedlings is greater than to transplants. Young plantswill often withstand flea beetle injury, but they may be killed if the weather is dry and windy. The percentage of plants affected and forecasted weather conditions will indicate the need to treat. Once established, plants can overcome moderate flea beetle feeding.

When the flea beetles on seedlings are migrating from hosts outside of the field, most of the infestation will be localized within 200 feet of borders. Check the distribution of plants that have evidence of leaf feeding to see if this is the case and consider border treatments only.

If high populations exist 1 to 2 weeks before harvest and foliage is declining as a food source for the beetles, spot-treat according to the distribution of the flea beetle.

Begin by monitoring the 5 rows adjacent to field edges and the first 25 feet at ends of rows. (No further sampling is needed if flea beetles are not present.) Look at leaves of 30 plants damaged by flea beetles. Expand the search area to delineate total area affected, if necessary.

Consider a spot treatment in rows that have 5-10% of seedlings or young plants with heavy flea beetle feeding. Once plants have more than 4 true leaves, treatment is not usually necessary.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

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A. DINOTEFURAN
(Venom) 1–4 oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A systemic insecticide that can be applied as a drench after seeding to control early season flea beetles. Apply in higher volume applications at 20 gallons/acre. Do not apply to cherry or grape tomatoes or to any variety with fruit less than 2 inches in diameter.

B. CLOTHIANIDIN
(Belay 50WDG) 1.6–2.1 fl oz 12 7
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Apply as a foliar spray. Do not apply during bloom or if bees are actively foraging.

C. THIAMETHOXAM
(Actara) 3–5.5 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. ESFENVALERATE*
(Asana XL) 9.6 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Use only against flea beetles late in season if fruit feeding is a concern. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. LAMBDA-CYHALOTHRIN*
(Warrior II with Zeon) 1.28–1.92 fl oz 24 5
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Use only against flea beetles late in season if fruit feeding is a concern.

F. PYRETHRIN#
(PyGanic EC1.4II) 16 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Always buffer pyrethrin to pH 5.5 or lower for best effect.

G. CARBARYL
(Sevin XLR Plus) 0.66–1.25 lb 12 3
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Spot treat with carbaryl just before harvest if fruit feeding is observed. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

H. ENDOSULFAN*
(Thionex 3EC) 0.66 qt 96 4
MODE-OF-ACTION GROUP NUMBER[1]: 2A
COMMENTS: Ground application recommended. Availability in many areas limited because of label restrictions for fields near waterways. Do not use after July 31, 2015.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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Acceptable for use on organically grown produce.

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GARDEN SYMPHYLANS (12/13)

Scientific Name: *Scutigerella immaculata*

DESCRIPTION OF THE PESTS

Garden symphylans, also called garden centipedes, are slender, white arthropods, closely related to insects, about 0.33 inch (8 mm long), with 10 to 12 prolegs and distinct antennae. These fast-moving arthropods live in soil and moveup and down in the soil profile in relation to the moisture gradient. After an irrigation they are near the soil surface. As the soil dries, they move deeper. They hide when exposed to light. They occur mainly in soil with high organic matter and especially in organic farms that fertilize with manures.

DAMAGE

Garden symphylans may damage seedlings before or after emergence and may slow the growth of larger plants. Damage usually is concentrated in relatively small areas and recurs every season; infestations spread slowly. In recent years symphylans have become serious pests of young, transplanted processing tomatoes in areas of the San Joaquin Valley and lower Sacramento Valley.

MANAGEMENT

This pest usually occurs in relatively small areas and in soils with a high organic matter. Reduce organic matter input and monitor known trouble spots to determine the need for spot treatments.

Cultural Control

- Reduce the amount of undecomposed plant material or manure that is applied to the soil. Wait to seed or transplant until the cover crop, soil-incorporated weeds, or manure has been broken down.
- Planting a higher seed population in problem areas may help compensate for damage.
- Rotate to tolerant crops such as beans, oats, or potatoes.

Organically Acceptable Methods

Cultural control is an organically acceptable management tool. Limited research has shown no significant control by organic soil amendments or essential oils.

Monitoring and Treatment Decisions

Research from other areas of the country indicates that symphylans can be detected with bait trapping. Either carrots or potatoes can be used as bait. Cut the bait in half longitudinally and scratch the cut surface just before placing it on the soil to ensure that the surface is moist. Place the bait at a depth where the soil is moist, and cover it with a plastic cup to exclude light and prevent the soil from drying. Use at least a dozen bait traps in the field. After 2 to 5 days,examine the cut surface and the soil upon which it was resting for evidence of symphylans. If they are detected, consider applying a pesticide.

Infested soil can be treated with an insecticide, but its effect is limited because of the symphylan's ability to migrate deep into the soil. Insecticides may help in giving the plants a chance to establish their roots in a protected zone. Treat for symphylans just before planting. Spot treatments may be adequate.

Common name (example trade name)	Amount per acre**	R.E.I‡ (hours)	P.H.I.‡ (days)

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A. LAMBDA-CYHALOTHRIN*
(Warrior II with Zeon) 1.28–1.92 fl oz 24 5
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Apply to soil in a minimum of 10 gallons water/acre next to or below the transplants with standard preplant fertilizer equipment just before transplants are set out in field. Use allowed under a FIFRA Section 2(ee) recommendation.

	Common name (example trade name)	Amount per acre**	R.E.I‡ (hours)	P.H.I.‡ (days)
B.	BETA-CYFLUTHRIN* (Baythroid XL) MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Apply to soil in a minimum of 10 gallons water/acre next to or below the transplants with standard preplant fertilizer equipment just before transplants are set out in field. A maximum of one pre-transplant application is allowed per crop season.	2.8 fl oz	12	0
C.	DIAZINON AG 600WBC* MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: Provides inconsistent control. Broadcast just before planting and immediately incorporate into the top 4 to 8 inches of soil.	51–102 fl oz	48	0

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

GREEN PEACH APHID and OTHER EARLY-SEASON APHIDS (12/13)

Scientific Name: *Myzus persicae* and others

DESCRIPTION OF THE PESTS

The green peach aphid and several other species are most commonly found on tomatoes early in the season. The green peach aphid is slender, dark green to yellow, with indefinite darker stripes on the abdomen, and no waxy bloom. This aphid is primarily an early-season pest and may transmit virus diseases to tomatoes.

DAMAGE

Green peach aphid infestations may result in wilting, but this damage is usually not of great concern unless the crop is water-stressed. Research indicates that early-season infestations may delay maturity but usually do not result in yield loss unless other factors are also present that enhance the injury. More importantly, these aphids vector pathogens such as *Alfalfa mosaic virus*.

MANAGEMENT

Conserve natural enemies by avoiding early-season use of disruptive insecticides. If virus transmission is a major concern, it may be economical to reduce or delay the early-season influx and buildup of aphid populations with the use of reflective mulches in fresh market tomatoes. These aphids do not usually require treatment.

Biological Control

Many parasites and predators attack aphids. Among the more common predators are lady beetles and their larvae, lacewing larvae, and syrphid fly larvae. Populations of green peach aphids are reduced in winter by a parasitic fungus, *Entomophthora aphidis*. Many materials available for aphid control are highly disruptive of natural enemy populations.

Cultural Control

Winged aphids are repelled by silver- or aluminum-colored mulches, which can significantly reduce colonization and delay the buildup of damaging numbers by 4 to 6 weeks. If there is a high probability of severe virus pressure, place reflective polyethylene mulches on planting beds before seeding or transplanting. While this approach is mainly effective in delaying or reducing the incidence of virus diseases transmitted by winged aphids and whiteflies, reflective mulches can also delay the buildup of wingless aphids that arise as a result of colonization by winged individuals. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting of either spring or fall tomatoes.

Organically Acceptable Methods

Cultural and biological controls and sprays of insecticidal soap, pyrethrin, or thyme oil are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Green peach aphids may move into early-season tomato seedlings but rarely require treatment. Early-season aphids have many natural enemies, including lady beetles, lacewings, syrphids, and parasites that frequently bring them under control later in the season.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. SPIROTETRAMAT
(Movento) 4–5 fl oz 24 1
MODE-OF-ACTION GROUP NUMBER[1]: 23

B. PYMETROZINE
(Fulfill) 2.75 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 9B
COMMENTS: Thorough spray coverage is essential for good control.

C. THIAMETHOXAM
(Actara) 3–5.5 oz 12 0
(Platinum) 5–11 fl oz 12 30
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS:Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. FLONICAMID
(Beleaf 50SG) 2–2.8 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 9C

E. ACETAMIPRID
(Assail 70WP) 1.2 oz 12 7
MODE-OF-ACTION GROUP NUMBER[1]: 4A

F. IMIDACLOPRID
(Admire Pro) 7–10.5 fl oz 12 21
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Effective against all early season aphid species. Most effective when soil or drip applied before or soon after transplanting. Do not apply to vegetables grown for seed.

G. DIMETHOATE
(Dimethoate 2.67EC) 1.5 pt 48 7
(Dimethoate 400) 1 pt 48 7
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

H. OXAMYL*
(Vydate L) 2–4 pt 48 3
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Do not use if psyllids are in the field as carbamates tend to promote development of their populations.

J. MALATHION Label rates 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites.

K. PYRETHRIN#
(PyGanic 1.4ECII) Label rates 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Short residual material. Always buffer pyrethrin to pH 5.5 or lower.

L. THYME OIL#
(Proud) Label rates 0 0
MODE OF ACTION: Contact including smothering and barrier effects.
COMMENTS: Short residual material. Research has not been conducted against green peach aphid in California, but it has been shown to be effective against melon aphid. Do not use if sulfur was applied recently or will be in the near future.

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
M.	INSECTICIDAL SOAP# (M-Pede)	2.5 oz/gal water	12	0
	MODE OF ACTION: A contact insecticide with smothering and barrier effects. COMMENTS: Can be used to reduce less than damaging populations, particularly when parasite activity is noted. Control is insufficient, however, when there is a high risk of virus transmission.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

HORNWORMS (12/13)

Scientific Names: Tobacco hornworm: *Manduca sexta;*
Tomato hornworm: *Manduca quinquemaculata*

DESCRIPTION OF THE PESTS

Hornworm eggs are laid singly on leaves. Eggs are round to oval, 1.5 mm in diameter, and white to light green.

While both species of hornworms have a large horn on the posterior end of the body, the tobacco hornworm has seven diagonal stripes on each side of the body in contrast to the tomato hornworm, which has eight chevron-shaped stripes. Larvae feed for 3 or 4 weeks, then burrow into the soil to pupate.

The adult moth is a strong flier with a wingspan up to 5 inches (12 cm). Developmenttakes about 2 months in summer; the winter is passed in the pupal stage. There are two generations a year in most areas; larvae are usually most common in midsummer, but there may be a small population peak in late summer. Infestations tend to be more severe in warm inland areas.

DAMAGE

Hornworms feed on blossoms, leaves, and fruit. At high populations they can extensively defoliate plants and scar the fruit. They are rarely a problem in the warmer interior valleys unless natural enemies are disrupted, in which case, they can do serious damage. They are mostly problems in garden situations.

MANAGEMENT

In commercial tomato fields, natural enemies, crop rotation, and discing after harvest play a key role in keeping hornworm populations below damaging levels. Conserve natural enemies by not treating with disruptive pesticides, especially early in the season before fruit begin to mature.

Biological Control

There are several important naturally occurring parasites that help control hornworms in tomatoes. Hornworm eggs are attacked by *Trichogramma* parasites and the larvae by *Hyposoter exiguae*. *Trichogramma* released for control of tomato fruitworm will also attack hornworm eggs.

Cultural Control

Discing after harvest destroys pupae in the soil. Rotations with crops that are not attacked by hornworms will also help to keep population levels low in individual fields.

Organically Acceptable Methods

Biological and cultural controls as well as *Bacillus thuringiensis* sprays are acceptable for use on an organically certified crop.

Monitoring and Treatment Decisions

Treat hornworms only if they are causing extensive foliage damage, or if they are feeding on fruit. Hornworm damage can be assessed as part of the sampling guidelines and thresholds listed under beet armyworm. Look for hornworm larvae on plants that have severe foliar damage as you sample to determine if damage is the result of hornworm or armyworm activity. In addition, hornworm feeding produces larger, deeper cavities than those caused by beet armyworm. Consider spot-treating sections of a field where hornworm damage is found because it is rare for an entire field to become infested.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. CHLORANTRANILIPROLE
(Coragen) 3.5–5 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Can be applied as foliar spray or by drip chemigation. Read label for treatment intervals.

B. METHOXYFENOZIDE
(Intrepid 2F) 8–16 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 18A
COMMENTS: Low toxicity to beneficials. Apply at the beginning of egg hatch. When traps indicate moth flights have begun, sample leaves for eggs. Treat when eggs are first detected.

C. FLUBENDIAMIDE
(Belt SC) 1.5 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. SPINETORAM
(Radiant SC) 5–10 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Apply as a foliar spray.

E. SPINOSAD
(Entrust)# 1.25–2.5 fl oz 4 1
(Success) 4–8 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Use higher rate for larger larvae and heavy infestations. Best control is achieved when aimed at newly hatched larvae and coverage is thorough. Less toxic to natural enemies than many other choices. For resistance management, do not apply more than 0.45 lb a.i./acre per season.

F. BACILLUS THURINGIENSIS spp. KURSTAKI#
(various products) Label rates 4 0
MODE-OF-ACTION GROUP NUMBER[1]: 11A
COMMENTS: This material is most effective against newly hatched larvae, so proper treatment timing is essential. This material is also somewhat effective on other lepidopteran pests.

G. NOVALURON
(Rimon 0.83EC) 9–12 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Apply at egg hatch to the second instar. Use higher rates when larvae are large or foliage canopy is tall or dense.

H. EMAMECTIN BENZOATE*
(Proclaim) 2.4–4.8 oz 12 7
MODE-OF-ACTION GROUP NUMBER[1]: 6

I. INDOXACARB
(Avaunt) 3.5 oz 12 3
MODE-OF-ACTION GROUP NUMBER[1]: 22

J. ESFENVALERATE*
(Asana XL) 5.8–9.6 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Use only under heavy pest pressure and close to harvest. Some resistance has been documented. May cause outbreaks of *Liriomyza* spp. Leafminers and tomato russet mite. In some areas where tomatoes are grown, resistance to this material is a problem. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
K.	FENPROPATHRIN* (Danitol 2.4EC)	10.66 fl oz	24	3
	MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Use only under heavy pest pressure and close to harvest. May cause outbreaks of *Liriomyza* spp. leafminers and tomato russet mites.			
L.	CARBARYL (XLR Plus)	1–2 qt	12	3
	MODE-OF-ACTION GROUP NUMBER[1]: 1A COMMENTS: Do not use if psyllids are in the field as carbamates tend to promote development of their populations. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

LEAFMINERS (12/13)

Scientific Names: *Liriomyza sativae, L. trifolii, L. huidobrensis and L. langei*

DESCRIPTION OF THE PESTS

Leafminer adults are small, black and yellow flies. *Liriomyza sativae* is shiny black on the upper surface except for a prominent yellow triangle between the bases of the wings; the underside and the face between the eyes are yellow. *Liriomyza trifolii* differs in having the thorax covered with overlapping bristles that gives fresh specimens a silvery gray color; specimens that are carelessly handled or placed in alcohol lose the gray and appear black. Also, the portion of the head behind the eyes is mostly yellow in *L. trifolii*, with only a small black area touching the rear edge of the eye; in *L. sativae*, the area behind the eyes is predominantly black. *Liriomyza huidobrensis* adults are similar to *L. trifolii*, but slightly larger. With practice, field identification is possible. However, you may wish to contact your local farm advisor for verification. The yellowish maggots and the brown, seedlike pupae of the three species are too similar to distinguish in the field.

The leafminers *Liriomyza sativae* and *L. trifolii* are common throughout California. Both species can reach damaging levels quite rapidly if certain disruptive insecticides are used repeatedly. *Liriomyza trifolii*, which appeared in the state in the late 1970s to early 1980s, is resistant to a wide spectrum of pesticides and has been the most common leafminer pest of tomatoes since 1990. There has been a recent change in the pest status of a related species, *L. huidobrensis*, which has suddenly become dominant on other vegetable crops grown in coastal California, and it appears to be spreading southward in the state. Reports are incomplete at this time on its status as a pest on tomatoes in California, but other parts of the world report significant losses on fresh market tomatoes.

The three leafminer species are similar in life history. Eggs are inserted in leaves and larvae feed between leaf surfaces, creating a meandering track or "mine." At high population levels, entire leaves may be covered with mines. Mature larvae leave the mines, dropping to the ground to pupate. The life cycle takes only 2 weeks in warm weather; there are seven to ten generations a year. All three species feed on a wide variety of crops and weeds; development continues all year and the population moves from one host to another as new host plants become available.

DAMAGE

Leafminer feeding results in serpentine mines (slender, white, winding trails); heavily mined leaflets have large whitish blotches. Leaves injured by leafminers drop prematurely; heavily infested plants may lose most of their leaves. If it occurs early in the fruiting period, defoliation can reduce yield and fruit size and expose fruit to sunburn. Pole tomatoes, which have a long fruiting period, are more vulnerable than other tomato crops. Leafminers are normally a pest of late summer tomatoes and can reach high numbers.

MANAGEMENT

The most important aspect of leafminer management is conserving their natural enemies, which are often killed by broad-spectrum insecticides applied forother tomato pests. Reduce the risk of leafminer outbreaks by applying insecticides for fruit pests only when monitoring shows treatment is needed and by choosing insecticides that are least likely to harm leafminer parasites.

Biological Control

Several species of parasitic wasps, particularly *Chrysocharis parksi* and *Diglyphus begini,* attack leafminer larvae; left undisturbed, parasites often keep leafminers numbers below economic injury levels.

Cultural Control

Check transplants for leafminers or mines before planting and destroy any plants that are infested; leafminers reach damaging levels earlier when infestations begin on transplants. Tomato varieties with curled leaves are less susceptible to leafminer damage and may provide suitable alternatives where leafminer damage is expected, as in fields adjacent to other infested crops. Where a series of tomato crops is planted in the same area, you can reduce early infestations in a new crop by removing old plantings immediately after the last harvest.

Organically Acceptable Methods

Biological and cultural controls as well as sprays of the Entrust formulation of spinosad are acceptable for use on an organically certified crop.

Monitoring and Treatment Decisions

A monitoring technique for leafminers in fresh market tomatoes is to place plastic trays about 12 by 15 inches in size beneath plants at several randomly chosen places in the field. Mature larvae that drop from foliage accumulate on the trays and pupate there, providing a measure of leafminer activity. A treatment threshold used experimentally for *L. sativae* and *L. trifolii* in southern coastal fresh market tomato fields is to treat when an average of 10 pupae per tray per day accumulates over a 3- or 4-day period. In all areas, do not treat unless pupae are present. Absence of pupae, even if new mines are present, indicates that parasitic wasps are suppressing leafminer numbers.

The dominant species of *Liriomyza* leafminers in California is in flux. However, all species are resistant to organophosphates, carbamates, and pyrethroids. If these types of insecticides are used, *Liriomyza* leafminer numbers will increase. Rotate applications of abamectin (also controls russet mite) and chlorantraniliprole or spinetoram. Some species are also controlled to a certain degree by spinosad.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label of the product being used.			
A. ABAMECTIN*			
(Agri-mek 0.15EC)	8–16 fl oz	12	7
MODE-OF-ACTION GROUP NUMBER[1]: 6			
COMMENTS: Apply in a minimum of 40 gal water per acre. This insecticide is the least toxic to beneficials of the insecticides listed. To delay the development of resistance, use in rotation with other insecticides.			
B. CHLORANTRANILIPROLE			
(Coragen)	3.5–5 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 28			
COMMENTS: Use with an adjuvant to increase penetration. Can be applied as foliar spray or by drip chemigation. Read label for treatment intervals.			
C. SPINETORAM			
(Radiant SC)	6–10 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 5			
D. SPINOSAD			
(Entrust)#	2–2.5 oz	4	1
(Success)	6–10 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 5			
COMMENTS: Does not significantly affect hymenopterous parasites of leafminers. Controls *Liriomyza sativae* and *L. trifolli*, but more research is being conducted to determine its effectiveness against *L. huidobrensis*. Ground applications provide better control than aerial ones. For resistance management, do not apply more than 3 times in any 21-day period.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

\# Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

LOOPERS (12/13)

Scientific Names: Alfalfa looper*: Autographa californica*; Cabbage looper: *Trichoplusia ni*

DESCRIPTION OF THE PESTS

Looper caterpillars are easily recognized because they crawl by arching their backs. Looper eggs are laid singly on the undersurface of mature leaves. They are similar to fruitworm eggs, but flatter, and have finer ridges radiating from the top.

DAMAGE

Loopers feed only on foliage, not on fruit. Damage is not serious enough to require control measures so treatment is rarely recommended.

MANAGEMENT

Although common in tomato fields, looper populations are generally kept below damaging levels by naturally occurring parasites and a viral disease. Moderate numbers of loopers are considered more beneficial than harmful because they serve as alternative hosts for parasitic wasps that also attack tomato fruitworms and other pest caterpillars. Treatment is only necessary if feeding is extensive enough that sunburn of the fruit is a concern. When insecticides are required, consider nondisruptive insecticides such as *Bacillus thuringiensis* to protect natural enemies.

Biological Control

There are several important naturally occurring parasites that help control loopers in tomatoes. One of these is *Hyposoter exiguae*, which also attacks tomato fruitworms and armyworms. Another parasitic wasp, *Copidosoma truncatellum*, commonly kills looper and other lepidopteran larvae by attacking the overwintering pupae. In southern California, looper eggs are often killed by *Trichogramma*; *Trichogramma* released for tomato fruitworm control often parasitize cabbage looper eggs as well. Alfalfa and cabbage loopers are also subject to disease caused by a nuclear polyhedrosis virus. Conserve these parasites by not treating with disruptive pesticides, particularly early in the season.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* or the Entrust formulation of spinosad are acceptable for use on an organically certified crop.

Monitoring and Treatment Decisions

Determine the extent of damage in the field. If damage is severe enough to expose fruit to sunburn, treat when tomatoes are at mid- to late-stage vegetative growth to maintain the plant canopy. Spot treat only severely infested areas.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. BACILLUS THURINGIENSIS spp. KURSTAKI#
(various products) — Label rates — 4 — 0
MODE-OF-ACTION GROUP NUMBER[1]: 11A
COMMENTS: This insecticide is most effective against newly hatched larvae, so proper treatment timing is essential. This insecticide is also somewhat effective on other lepidopteran pests.

B. CHLORANTRANILIPROLE
(Coragen) — 3.5–5 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Can be applied as foliar spray or by drip chemigation. Read label for treatment intervals.

C. METHOXYFENOZIDE
(Intrepid 2F) — 8–16 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 18A
COMMENTS: Low toxicity to beneficials. Apply at the beginning of egg hatch. When traps indicate moth flights have begun, sample leaves for eggs. Treat when eggs are first detected.

D. FLUBENDIAMIDE
(Belt SC) — 1.5 fl oz — 12 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. SPINETORAM
(Radiant SC) — 5–10 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Apply as a foliar spray.

F. SPINOSAD
(Entrust)# — 1.25–2.5 fl oz — 4 — 1
(Success) — 4–8 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Use higher rate for larger worms and heavy infestations. Best control is achieved when aimed at newly hatched larvae and coverage is thorough. Less toxic to natural enemies than many other choices. For resistance management, do not apply more than 0.45 lb a.i./acre per season.

G. NOVALURON
(Rimon 0.83EC) — 9–12 fl oz — 12 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Apply at egg hatch to the second instar. Use higher rates when larvae are large or foliage canopy is tall or dense.

H. EMAMECTIN BENZOATE*
(Proclaim) — 2.4–4.8 oz — 12 — 7
MODE-OF-ACTION GROUP NUMBER[1]: 6

I. INDOXACARB
(Avaunt) — 3.5 oz — 12 — 3
MODE-OF-ACTION GROUP NUMBER[1]: 22

J. METHOMYL*
(Lannate SP) — 0.5–1 lb — 48 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Will also control fruitworm, yellowstriped armyworm, cutworms, and cabbage looper. Primary use of methomyl should be if older larvae, which are difficult to control with other insecticides, are present. Some resistance has been documented. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
K. ESFENVALERATE* (Asana XL)	5.8–9.6 fl oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Use only under heavy pest pressure and close to harvest. Some resistance has been documented. May cause outbreaks of *Liriomyza* spp. Leafminers and tomato russet mite. In some areas where tomatoes are grown, resistance to this material is a problem. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
L. FENPROPATHRIN* (Danitol 2.4EC)	10.66 fl oz	24	3
MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Use only under heavy pest pressure and close to harvest. May cause outbreaks of *Liriomyza* spp. leafminers and tomato russet mites.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval(P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

LYGUS BUGS (12/13)

Scientific Name: *Lygus hesperus* and others

DESCRIPTION OF THE PESTS

Adults are yellowish, brownish, or greenish bugs, about 0.3 inch (7–8 mm) in length, with a conspicuous triangle in the center of the back that is tinged brown, red, or yellow. Nymphs resemble adults, but are uniformly pale green with red-tipped antennae and have no wings. Lygus feed on the fruit or seeds of many flowering plants, including alfalfa and safflower. They can move to tomatoes when their primary hosts dry or are disturbed, such as when alfalfa is cut, safflower dries, or weedy fields of sugar beets are harvested.

For additional information on identifying lygus bugs, see *A Field Key to the Most Common Lygus Species Found in Agronomic Crops of the Central San Joaquin Valley of California*, UC ANR Publication 8104, which can be found online at anrcatalog.ucdavis.edu.

DAMAGE

On the surface of the fruit, lygus bug damage is similar to that of stink bug damage immediately after feeding. The area below the feeding site, however, dries instead of becoming corky, causing the surface of the fruit to crack slightly. Therefore, damage is not as apparent. Lygus feeding has not been associated with the transmission of yeast pathogens like with stink bugs.

MANAGEMENT

Treatment is not recommended for tomatoes to be used for paste or juice. However, if large numbers of lygus are present in fields intended for fresh market or whole pack processing, treatment may be warranted. Check with your processor regarding the significance of lygus damage to their product.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. FLONICAMID
(Beleaf 50SG) — 2–2.8 oz — 12 — 0
MODE-OF-ACTION GROUP NUMBER[1]: 9C
COMMENTS: Research is lacking on the effectiveness on this insecticide in tomato, but it has proven to be effective against lygus bug in other crops such as cotton and strawberry and not as detrimental to natural enemies as other products.

B. FENPROPATHRIN*
(Danitol 2.4EC) — 10.66 fl oz — 24 — 3
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Do not use this product if leafminers are presentbecause it is destructive of their parasites.

C. CLOTHIANIDIN
(Belay 50WDG) — 1.6–2.1 fl oz — 12 — 7
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Apply as a foliar spray. Do not apply during bloom or if bees are actively foraging.

D. ENDOSULFAN*
(Thionex 3EC) — 0.66 qt — 96 — 4
MODE-OF-ACTION GROUP NUMBER[1]: 2A
COMMENTS: Ground application recommended. Availability in many areas limited because of label restrictions for fields near waterways. Do not use after July 31, 2015.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
E. METHOMYL*			
(Lannate SP)	0.5–1 lb	48	1
(Lannate LV)	1.5–3 pt	48	1
MODE-OF-ACTION GROUP NUMBER[1]: 1A			
COMMENTS: This material will also control armyworm and cabbage looper. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies.			
F. DIMETHOATE			
(Dimethoate 2.67EC)	1.5 pt	48	7
(Dimethoate 400)	1 pt	48	7
MODE-OF-ACTION GROUP NUMBER[1]: 1B			
COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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POTATO APHID (12/13)

Scientific Name: *Macrosiphum euphorbiae*

DESCRIPTION OF THE PEST

The potato aphid has both a pink and a green color biotype. This aphid is much bigger than the green peach aphid with a more elongate body shape and is generally found on the terminals of tomato plants later in the season than green peach aphids. It is also considered to be more damaging.

DAMAGE

High potato aphid populations can distort leaves and stems, stunt plants, and cause necrotic spots on leaves. These aphids also secrete a large amount of honeydew that promotes development of sooty mold on foliage and fruit. Plants are particularly susceptible to yield losses from high infestations during the period from 6 to 8 weeks before harvest. Yield losses from equally high aphid populations decline substantially as harvest approaches, unless aphid densities are reducing leaf area enough to permit sunburn.

MANAGEMENT

Monitor potato aphids from 6 to 8 weeks before harvest as well as the level of parasitism and the activity level of predators. Treatments may be necessary if natural enemy activity is low and populations are increasing.

Biological Control

Naturally occurring parasites and predators of the potato aphid are common and can provide control. Monitor the proportion of aphid mummies relative to unparasitized aphids and the numbers of predators such as lady beetles, lacewing larvae, and syrphid larvae. If the proportion of mummies is increasing or predators appear to be gaining control and aphid populations are not yet damaging, avoid sprays that will disrupt these natural enemies.

Tolerant Varieties

There is considerable difference in tomato variety susceptibility to potato aphid feeding. Varieties containing the Mi gene, which confers resistance to nematodes, have been reported to be more tolerant of potato aphid infestations. However, this resistance no longerappears to be as effective as it once was, particularly against the pink form of the potato aphid.

Organically Acceptable Methods

The use of tolerant varieties, biological control, and sprays of herbal oils, pyrethrin, or insecticidal soapare acceptable for use on an organically certified crop. Repeated applications may be necessary for control.

Monitoring and Treatment Decisions

- Monitor potato aphids from bloom to early fruit set by picking the highest open flower on 30 plants selected at random throughout the field.
- Record on a monitoring form (available online) the presence or absence of potato aphids on each leaf, while noting natural enemies.
- Treat if 50 to 60% or more of the leaves are infested.
- During late fruit set, combine monitoring for potato aphid with monitoring for tomato fruitworm:
  - Pick the leaf below the highest open flower on 30 randomly selected plants from throughout the field.
  - Record observations on a monitoring form *(available online)*.
  - Consider a pesticide application. If 50% of these leaves are infested during the period 6 to 8 weeks before harvest, the resulting loss is about 1 ton per acre, and a pesticide application should be made.

Good spray coverage is important in controlling high populations. Ground sprays using hollow-cone nozzles or air-assist sprayers will provide the best canopy penetration. Higher spray volumes are also helpful.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. SPIROTETRAMAT
(Movento) 4–5 fl oz 24 1
MODE-OF-ACTION GROUP NUMBER[1]: 23

B. FLONICAMID
(Beleaf 50SG) 2.8 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 9C

C. THIAMETHOXAM
(Actara) 2–3 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. IMIDACLOPRID
(Admire Pro) 7–10.5 fl oz 12 21
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Most often applied in drip or trickle irrigation water. Can be used preventively as a systemic in areas with chronic infestations. Apply as a sidedress within 4 inches on either side of plants and incorporate to a depth of 2 to 3 inches. Treat at first bloom up to 8 weeks before harvest. Apply sufficient water following application to move into the root zone of the plant. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. PYMETROZINE
(Fulfill) 2.75 oz 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 9B

F. ACETAMIPRID
(Assail 70WP) 1.2 oz 12 7
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

G. DIMETHOATE
(Dimethoate 2.67EC) 1.5 pt 48 7
(Dimethoate 400) 1 pt 48 7
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

H. THYME OIL#
(Proud) Label rates 0 0
MODE OF ACTION: Contact including smothering and barrier effects.
COMMENTS: Short residual material. Do not use if sulfur was applied recently or will be in the near future.

I. PYRETHRIN#
(PyGanic 1.4ECII) Label rates 12 0
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Short residual material that provides moderate control with repeated applications. Always buffer to pH 5.5 or lower.

J. ROSEMARY OIL + PEPPERMINT OIL#
(Ecotrol) 1–1.5 pt 0 0
MODE OF ACTION: Contact including smothering and barrier effects.
COMMENTS: Short residual material. Apply with organic spreader and sticker. Do not use if sulfur was applied recently or will be in the near future.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
K. INSECTICIDAL SOAP# (M-Pede)	2.5 oz/gal water	12	0

MODE OF ACTION: A contact insecticide with smothering and barrier effects.
COMMENTS: Soaps provide less than 50% control of potato aphid, but can be used to reduce numbers, particularly when parasite activity is noted.

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

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POTATO TUBERWORM (12/13)

Scientific Name: *Phthorimaea operculella*

DESCRIPTION OF THE PEST

Potato tuberworm infestations are not common in California, but when they do occur it is most often on the coast and in the southern San Joaquin Valley. Serious infestations are almost always associated with potato culture. Where tomatoes follow potatoes and where there are volunteer potato plants, there is always the danger of a serious infestation. Larvae of the tuberworm, when fully grown, are pinkish gray, with a brown head and prothoracic shield.

DAMAGE

Potato tuberworm larvae prefer to enter the fruit at the calyx end, making a dry burrow through the core and the fleshy portions that radiate from it, but they may enter at any point on the fruit's surface. They usually spin a web over the entrance to their burrows, and the fruit must be carefully observed to detect damage.

MANAGEMENT

No control guidelines at this time other than to avoid planting tomatoes after or near infested potato fields or cull piles.

STINK BUGS (12/13)

Scientific Names: Consperse stink bug: *Euschistus conspersus*
Redshouldered stink bug: *Thyanta pallidovirens (= T. accerra)*
Say stink bug complex: *Chlorochroa sayi* and *Chlorochroa uhleri*
Southern green stink bug: *Nezara viridula*

DESCRIPTION OF THE PESTS

Several kinds of stink bugs feed on tomatoes,but all are similar in life history and damage. The most common species statewide is the consperse stink bug, which tends to be the most important species in the Sacramento and northern San Joaquin valleys. The redshouldered stink bug is considered the most prevalent species in the southern San Joaquin Valley. *Chlorochroa sayi* and *C. uhleri* are most prevalent on the west side of the San Joaquin Valley. The southern green stink bug, *Nezara viridula*, occurs in parts of the Sacramento and northern San Joaquin valleys, but is kept at relatively low levels by an imported parasite. Two exotic stink bugs, the bagrada bug, *Bagrada hilaris*, currently found only in southern California, and the brown marmorated stink bug, *Halyomorpha halys*, are also capable of damaging tomatoes but neither have been found in commercial fields.

Adult stink bugs are distinctly shield shaped and either brown or green. Some species have red, pink, or yellow markings. Adults overwinter on the ground under leaves, in protected areas such as woodpiles in orchards, legume crops, blackberries, or on certain weeds such as Russian thistle, mustards, and little mallow (cheeseweed). They become active in March and April and begin laying eggs at this time. Eggs are drum-shaped with circular lids and are laid in clusters on foliage. Immatures resemble adults but do not have developed wings.

DAMAGE

On green fruit, damage appears as dark pinpricks, surrounded by a light discolored area that turns yellow or remains light green on ripe fruit. Fissures below the surface turn corky. Stink bugs may also carry yeast and other pathogens on their mouthparts that may cause fruit decay when introduced during feeding. A few fields have been significantly damaged by yeast introduced by stink bugs; this damage is scored as "mold" by state graders.

MANAGEMENT

Monitoring stink bug populations and their levels of parasitism are important for making treatment decisions. Treatment thresholds vary according to the market for which the crop is grown.

Biological Control

Both predators and parasites attack stink bug egg masses. One parasitic wasp, *Trissolcus basalis*, has been introduced into California for control of the southern green stink bug. Examine stink bug eggs to determine levels of parasitization. Parasitized eggs are dark; if parasites have emerged, the emergence holes will be irregular as opposed to round holes caused by stink bugs pushing off the top cap of the eggs to emerge. *Trissolcus basalis* does not appear to parasitize the other stink bug species in the field. However, a large complex of native parasites do parasitize these native stink bug species; these parasites occur in most growing areas and can result in parasitism in excess of 80% late in the season. Although not commercially available, monitoring for stink bug egg masses to detect black eggs (those that are parasitized) is a useful practice. If parasitized egg masses are found, treatment for newly hatched nymphs might not be necessary. If damaging levels of nymphs and adults are present, treatment will still be needed. Parasitism can be enhanced for short distances from plantings of nectar plants such as alyssum and others as long as the flowering of these plants begins early in the season (April–June).

Cultural Control

Destroy weeds (legumes, blackberries, Russian thistle, mustards, and little mallow) that are goodoverwintering hosts for adult stink bugs around fields that are to be planted to tomatoes in spring.

Organically Acceptable Methods

Preserving naturally occurring biological control agents, good weed management around the field, and kaolin clay and insecticidal soap sprays are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Stink bugs are often not observed until damage has begun. When the bugs are common, they may be found by beating or by shaking the vines. After shaking, look for stink bugs on the ground and between clods of soil. Or place a 16-inch cafeteria-style tray on the ground and shake the plant onto that. The presence of stink bugs can also be detected by their brown liquid frass, which dries into spots (0.06–0.12 inch) on leaves and fruit where they

are active. Treatment is more likely to be necessary in fresh market plantings and in processing fields committed to solid-pack or dice canning. Treatment is generally notrecommended in processing tomatoes intended for paste or juice unless conditions, such as wet, dense canopies, are favorable for the development of yeast or fungal pathogens introduced by the bugs during feeding.

To monitor consperse stink bug activity and distribution in a field, place clean, double-cone traps baited with an aggregation pheromone in fields at flowering. (Pheromones are not commercially available for the other species. A pheromone is commercially available for brown marmorated stink bug to be used with a rocket-type trap.) In areas of the field where stink bugs are consistently found in traps, take samples beginning when fruit reach one inch in diameter. Sample with a beating sheet or tray, and also examine the soil under the beating.

A phenology model has been developed for consperse stink bug that can help predict nymphal emergence. Newly hatched nymphs are most easily controlled by pesticides. To use the phenology model, *(available at the UC IPM Web site, www.ipm.ucdavis.edu)*begin calculating degree-days from the date adult stink bugs are first captured in pheromone traps. The lower developmental threshold is 53.6°F (12°C); no upper developmental threshold has been established, although it is believed to be near 98.6°F (37°C). Most nymphs will be present at about 558 DD (°F) or 310 DD (°C), and shake sampling as described previously to determine the need for treatment should be made at this time.

Treatment thresholds vary according to the use of the tomatoes, but a good rule is that one-third to one-half of a stink bug per tray shake on average will result in about 5% damaged fruit. Distribution of samples within the field depend on whether an area of the field can be treated separately from the whole field. If an infested portion of the field cannot be spot treated, average tray shake samples from the entire field to make a treatment decision.

Be aware of the following to improve stink bug control with insecticides.

- Good canopy penetration of insecticides is essential because most stink bugs are located on the ground at any given time of day.
- Apply via ground equipment; ground applications provide much better coverage than do aerial sprays that cannot reach bugs deep within the plant canopy or on the soil under the plants.
- Use hollow-cone nozzles or air-assist sprayers to improve canopy penetration.
- Consider reducing tractor speed and increasing application volume to improve coverage.
- If water volume is increased, use the highest label rate of pesticide.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.			
A. LAMBDA-CYHALOTHRIN* (Warrior II with Zeon) MODE-OF-ACTION GROUP NUMBER[1]: 3A	1.28–1.92 fl oz	24	5
. . . PLUS . . .			
NOVALURON (Rimon 0.83EC) MODE-OF-ACTION GROUP NUMBER[1]: 15	12 fl oz	12	1
. . . OR . . .			
ACETAMIPRID (Assail 70WP) MODE-OF-ACTION GROUP NUMBER[1]: 4A	1.7 oz	12	7
COMMENTS: Do not use pyrethroids (Group number 3) if leafminers are present because it is destructive to their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
B.	METHOMYL* (Lannate SP) MODE-OF-ACTION GROUP NUMBER[1]: 1A *. . . PLUS . . .* FENPROPATHRIN* (Danitol 2.4EC) MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Do not use Group number 1A insecticides if psyllids arein the field as carbamates tend to promote development of their populations. Do not use either product if leafminers are present because it is destructive of their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.	0.5 lb 10.66 fl oz	48 24	1 3
C.	ENDOSULFAN* (Thionex 3EC) MODE-OF-ACTION GROUP NUMBER[1]: 2A COMMENTS: Ground application recommended. Availability in many areas limited because of label restrictions for fields near waterways. Do not use after July 31, 2015.	0.66 qt	96	4
D.	KAOLIN CLAY# (Surround) MODE OF ACTION: An inorganic insecticide. COMMENTS: Kaolin clay does not appear to kill stink bugs directly but is quite effective in protecting the fruit surface from feeding. Begin applications when stink bugs are present and fruit are mature green to pink. Apply to protect the surface of the fruit; canopy penetration is essential. A repeat application may be needed if fruit reaching the susceptible stage are not coated. Kaolin clay application results in a thick, white deposit that coats the foliage and fruit and must be washed from the fruit, limiting its potential for use.	30–50 lb	4	0
E.	FLONICAMID (Beleaf 50SG) MODE-OF-ACTION GROUP NUMBER[1]: 9C COMMENTS: Research is lacking on the effectiveness on this insecticide in tomato, but it has proven to be effective against lygus bug in other crops such as cotton and strawberry and not as detrimental to natural enemies as other products.	2–2.8 oz	12	0
F.	CLOTHIANIDIN (Belay 50WDG) MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Apply as a foliar spray. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging. Can be tank-mixed with a pyrethroid insecticide.	1.6–2.1 fl oz	12	7
G.	FENPROPATHRIN* (Danitol 2.4EC) MODE-OF-ACTION GROUP NUMBER[1]: 3A *. . . PLUS . . .* PYRIPROXYFEN (Knack) MODE-OF-ACTION GROUP NUMBER[1]: 7C COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.	10.66 fl oz 8 fl oz	24 12	3 14
H.	FENPROPATHRIN* (Danitol 2.4EC) MODE-OF-ACTION GROUP NUMBER[1]: 3A *. . . PLUS . . .* ACETAMIPRID (Assail 70WP) MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	10.66 fl oz 1.7 oz	24 12	3 7

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
I.	BETA-CYFLUTHRIN*			
	(Baythroid XL)	2.8 fl oz	12	0
	MODE-OF-ACTION GROUP NUMBER[1]: 3A			
	. . . PLUS . . .			
	IMIDACLOPRID			
	(various foliar products)	Label rates	See label	See label
	MODE-OF-ACTION GROUP NUMBER[1]: 4A			
	COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
J.	LAMBDA-CYHALOTHRIN*			
	(Warrior II with Zeon)	1.28–1.92 fl oz	24	5
	MODE-OF-ACTION GROUPNUMBER[1]: 3A			
	COMMENTS: Timing is essential for success. Use the **c**onsperse stink bug phenology model to time treatment against nymphs***(available online at*** *http:// www.ipm.ucanr.edu).* Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
K.	METHOMYL*			
	(Lannate SP)	0.5 lb	48	1
	MODE-OF-ACTION GROUP NUMBER[1]: 1A			
	. . . PLUS . . .			
	ESFENVALERATE*	5.8–9.6 fl oz	12	1
	(Asana XL)			
	MODE-OF-ACTION GROUP NUMBER[1]: 3A			
	COMMENTS: Neither pesticide is effective against stink bugs alone; must be used in a tank mix. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not use Group number 1A insecticides if psyllids are in the field as carbamates tend to promote development of their populations. Do not use either product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
L.	IMIDACLOPRID			
	(Admire Pro)	7–10.5 fl oz	12	21
	MODE-OF-ACTION GROUP NUMBER[1]: 4A			
	COMMENTS:Most often applied in drip or trickle irrigation water. Can be used preventively as a systemic in areas with chronic infestations. Apply as a sidedress within 4 inches on either side of plants and incorporate to a depth of 2 to 3 inches. Treat at first bloom up to 8 weeks before harvest. Apply sufficient water following application to move into the root zone of the plant. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
M.	INSECTICIDAL SOAP#			
	(M-Pede)	2.5 oz/gal water	12	0
	MODE OF ACTION: A contact insecticide with smothering and barrier effects.			
	COMMENTS: Not effective against adults; only kills nymphs through direct contact so thorough coverage is critical. Expected field efficacy with excellent coverage is 30 to 50%.			

** See label for dilution rates.

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THRIPS (12/13)

Scientific Names: Western flower thrips: *Frankliniella occidentalis*
Onion thrips: *Thrips tabaci*
and other species

DESCRIPTION OF THE PESTS

Thrips are very small, slender insects that are best seen with a hand lens. Mature western flower thrips are 0.06 inch (1.5 mm) long, while onion thrips are slightly smaller at 0.05 inch (1.3 mm) long. The most distinctive characteristic of thrips is two pairs of wings that are fringed with long hairs. Adults are pale yellow to light brown in color. Immature stages have the same body shape as adults but are lighter in color and are wingless.

Thrips have a very extensive host range, including cereals, onions, garlic, and broadleaved crops, but it is only the species of plants that are infected by *Tomato spotted wilt virus* and on which the thrips can complete their entire life cycle that play an important role in the disease cycle. In California, the key crop hosts include tomato, pepper, lettuce, radicchio and fava bean. Important weed hosts include cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus)*, and prickly lettuce (*Lactuca serriola*).

The adults are the only life stage that can fly, but they are not strong fliers. Adult thrips can be carried on wind currents, on clothing, and in association with plants. The length of the thrips life cycle (from egg to adult) varies depending on environmental conditions but is generally 30 to 45 days, though it can be as little as 14 days.

DAMAGE

The primary damage caused by thrips to tomatoes is the vectoring of *Tomato spotted wilt virus*. The virus can only be acquired by the immature stage of thrips, whereas plant-to-plant transmission primarily occurs by adults. The adult thrips can transmit the virus for the remainder of their lives, which can last 30 to 45 days. However, the adults do not pass the virus to their progeny (through the egg).

High numbers of thrips can cause damage with their feeding, which distorts plant growth, deforms flowers, and causes white-to-silvery patches on emerging leaves that often have tiny black fecal specks in them.

MANAGEMENT

If possible, avoid planting tomatoes next to onions, garlic, or cereals, because high thrips numbers often build up on these crops. Also, avoid fields near greenhouses where ornamentals (cut flowers) are grown because these plants serve as hosts for the virus and thrips.

Insecticide treatments for thrips are usually not warranted in the Imperial Valley but may be needed for suppression of *Tomato spotted wilt virus* in the Central Valley and coastal growing areas.

Treatment with foliar insecticide sprays early in the season and continuing through the season as needed may limit in-field spread of *Tomato spotted wilt virus* to some extent. Soil applied imidacloprid has not been shown to lower virus incidence. Rotate classes of insecticides to minimize insecticide resistance in thrips.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.			
A. SPINETORAM			
(Radiant SC)	6–10 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 5			
B. SPINOSAD			
(Entrust)#	1.25–2.5 oz	4	1
(Success)	4-8 oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 5			

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
C. DINOTEFURAN			
(Venom)	1–4 oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 4A			
COMMENTS: Do not use on tomato varieties that are less than 2 inches (cherry or grape tomatoes). Apply to foliage not through drip irrigation to reduce thrips numbers.			
D. METHOMYL*			
(Lannate SP)	0.25–0.5 lb	48	1
(Lannate LV)	0.75–1.5 pt	48	1
MODE-OF-ACTION GROUP NUMBER[1]: 1A			
COMMENTS: Do not use if psyllids are present. Efficacy increases when combined with a pyrethroid such as zeta-cypermethrin (Mustang).			
E. DIMETHOATE			
(Dimethoate 400)	0.5–0.66 pt	48	0
(Dimethoate 2.67EC)	0.75–1 pt	48	0
MODE-OF-ACTION GROUP NUMBER[1]: 1B			
COMMENTS: Do not use if psyllids are present. Efficacy increases when combined with a pyrethroid such as zeta-cypermethrin (Mustang). Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
F. FLONICAMID			
(Beleaf 50SG)	2.8 oz	12	0
MODE-OF-ACTION GROUP NUMBER[1]: 9C			

** See label for dilution rates.

\+ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

[1] Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

\# Acceptable for use on organically grown produce.

TOMATO BUG (12/13)

Scientific Name: *Cyrtopeltis modesta*

DESCRIPTION OF THE PEST

The tomato bug is a slender plant bug, about 0.25 inch (6 mm) long, with long legs and a light green body. Eggs are inserted into stems. Nymphs resemble adults but are smaller and lack wings.

DAMAGE

The tomato bug is also known as the tomato suck bug because both nymphs and adults will insert their long mouthparts into the stem to feed. Rings develop around stems at these feeding sites. The rings are thickened corky areas that become yellow to reddish. The stem is weakened and brittle at these rings and can easily break when touched, causing blossom drop, dropping of young fruit, and breakage of vine stems.

Tomato bugs are common in tomato fields throughout the Central Valley and in southern California, but they do not typically cause economic damage to bush-type processing or fresh market tomato plants where fruit are picked only once. They have been observed on occasion in great abundance on commercially grown pole tomatoes, in greenhouse culture, and in back yard gardens. Economic damage has been observed in pole and greenhouse plantings when blossoms drop and vines break at feeding sites when vines are contacted by workers moving past the plants.

MANAGEMENT

Tomato bugs are usually first noticed in mid-summer, and their populations continue to grow into fall, when treatments may become necessary. In general, treatments are not recommended except when high densities occur in pole or greenhouse tomato plantings which are picked multiple times. Although no research has been conducted on control it is believed that most insecticides used to control lygus bugs or stink bugs will also control the tomato bug.

TOMATO FRUITWORM (12/13)

Scientific Name: *Helicoverpa (Heliothis) zea*

DESCRIPTION OF THE PEST

Tomato fruitworm adults are medium-sized moths with a wingspan of about 1 to 1.3 inch (25–35 mm). They are pale tan to medium brown colored or sometimes have a slight greenish tinge. The front wings are variously marked and usually have an obscure dark spot in the center and a lighter band inside a dark band around the tip. The hind wings are drab white and have a dark gray band around their tip. A diffuse light spot is in the center of the dark band.

At hatching, tomato fruitworm larvae are creamy white caterpillars with a black head and conspicuous black tubercles and hairs. Larger larvae vary in color from yellowish green to nearly black and develop fine white lines along the body but retain the black spots at the base of bristlelike hairs. Older larvae also have patches of stubby spines on their body segments that are much shorter than the bristles and can be seen best with the use of a hand lens.

The tiny, spherical eggs are slightly flattened on top with coarse striations or ribs runningfrom base to tip. They are easy to confuse with looper eggs, but looper eggs have finer striations. Fruitworm eggs are laid singly on both upper and lower surfaces of the leaves usually in the upper part of the plant. When first laid, eggs are creamy white, but develop a reddish brown ring after 24 hours and darken just before larvae hatch.

Tomato fruitworm is also called cotton bollworm and corn earworm.

DAMAGE

When there is fruit present, the tomato fruitworm will complete its larval development inside fruit. Early stage larvae enter the stem end of fruit when it is between 0.75 to 2 inches in diameter. During development, caterpillars may emerge from one fruit and enter another. Their feeding results in a messy, watery, internal cavity filled with cast skins and feces. Damaged fruit will ripen prematurely. Late in the season, small larvae will also enter ripe fruit. Small larvae are difficult to detect and, thus, may be a problem in processing tomatoes for the canner. In fresh market tomatoes, any feeding results in unmarketable fruit that will need to be culled at harvest or in the packing shed.

MANAGEMENT

Management of tomato fruitworm requires careful monitoring for eggs and small larvae. When control is needed, it is essential to treat before large numbers of larvae enter fruit, where they are protected from sprays. *Trichogramma* parasites and other natural enemies often destroy significant numbers of eggs, so it is important to check for parasitism and predation before making treatment decisions. Early-season processing tomatoes rarely need treatment. Late-season fields may be more seriously affected.

Biological Control

Naturally occurring beneficial insects are very important in the biological control of tomato fruitworm, especially in the Delta area and the Sacramento Valley. These include *Trichogramma* spp. egg parasites, the larval parasite *Hyposoter exiguae*, and predators such as bigeyed bug and minute pirate bug. Conserve these parasites and predators whenever possible and monitor their presence, as described in MONITORING AND TREATMENT DECISIONS.

A tomato fruitworm egg parasite, *Trichogramma pretiosum*, is available from many commercial insectaries. Inundative release of 100,000 parasites/acre during the period of fruitworm oviposition and when fruit are susceptible to fruitworm feeding can help prevent unacceptable levels. Monitor the success of *Trichogramma pretiosum* releases using the egg sampling technique (indicated by black, parasitized eggs) and use the table below to determine if pesticide treatments are needed. Be sure to monitor the releases to make certain that parasitism is occurring.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Damaging populations of tomato fruitworm rarely occur before August. Monitoradult activity in July using a Heliothis trap baited with a pheromone lure to determine when to sample for eggs, which are laid during the flight periods. When moths are being caught in the traps, begin sampling leaves for eggs. If eggs are detected in samples taken during July, start accumulating degree-days using a lower threshold of 55°F and an upper threshold of 92°F to predict egg laying of the generation in August that attacks the fruit. It takes an average of 968 degree-days for tomato fruitworm to complete a generation. (For assistance in calculating degree-days, see "'Degree-days"' on the UC IPM Web site at http://www.ipm.ucanr.edu.)

Fresh market tomatoes

Traps may be helpful to determine when a flight has begun. Conduct a 5-minute search of leaves for eggs. If eggs are found, a treatment may be warranted. Later in the season, sample both leaves and fruit when monitoring for caterpillars (tomato fruitworm, beet armyworm, etc.).

Processing tomatoes

Start sampling for eggs when a significant number of green fruit are one inch in diameter, sample for eggs by picking the leafbelow the highest open flower on 30 plants selected at random throughout the field. If three or more healthy, white eggs are found in the 30-leaf sample, sample 30 more leaves (stop sampling if less than 3 eggs are found). If five or more eggs are found in the second 30-leaf sample, apply a treatment to coincide with hatching. Aim insecticide treatments at newly hatched larvae. Once larvae are in fruit they have already caused damage and are difficult to kill. When sampling for fruitworm, also look for fruitworm damage. Six to eight weeks before harvest, also monitor potato aphids in your sample and record results on a monitoring form *(available online).*

Assess egg parasitism for processing tomatoes in the Sacramento Valley

In the Sacramento Valley, several species of parasitic wasps (*Trichogramma* spp.) can be found parasitizing tomato fruitworm eggs in late August and September at sufficient densities to control the pest. Most, but not all parasitized eggs will eventually turn black. Because there is a lag period, some white eggs in field samples may actually be parasitized but not recognizable as such; consequently a threshold may falsely appear to be exceeded. The following table provides adjusted treatment thresholds, using the number of black and white eggs present in samples of 30 tomato leaves, to compensate for not being able to distinguish eggs in the early stagesof parasitism.

The letter "T" indicates the ratio at which treatment is recommended. If no black eggs are recorded, collect and observe white eggs for 48 hours and subtract those that turn black due to parasitism.

Number of Black Eggs	Number of White Eggs							
	4–8	9	10	11	12	13	14	15
0	T	T	T	T	T	T	T	T
1		T	T	T	T	T	T	T
2				T	T	T	T	T
3					T	T	T	T
4						T	T	T
5						T	T	T
6						T	T	T
7							T	T
8							T	T
9								T
10								T

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label of the product being used.

A. METHOXYFENOZIDE
(Intrepid 2F) — 10–16 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 18
COMMENTS: Low toxicity to natural enemies. Time application to the beginning of egg hatch. When traps indicate moth flights have begun, sample leaves for eggs. Treat when eggs are first detected.

B. CHLORANTRANILIPROLE
(Coragen) — 3.5–5 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Can be applied as either a foliar application or in drip chemigation.

C. FLUBENDIAMIDE
(Belt SC) — 1.5 fl oz — 12 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. NOVALURON
(Rimon 0.83EC) — 9–12 fl oz — 12 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENTS: Apply at egg hatch to the second instar. Use higher rates when larvae are large or foliage canopy is tall or dense. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. SPINETORAM
(Radiant SC) — 5–10 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 5

F. SPINOSAD
(Entrust)# — 1–2 — 4 — 1
(Success) — 3–6 fl oz — 4 — 1
MODE-OF-ACTION GROUP NUMBER[1]: 5

G. EMAMECTIN BENZOATE*
(Proclaim) — 2.4–4.8 oz — 12 — 7
MODE-OF-ACTION GROUP NUMBER[1]: 6

H. INDOXACARB
(Avaunt) — 3.5 oz — 12 — 3
MODE-OF-ACTION GROUP NUMBER[1]: 22A
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

I. BACILLUS THURINGIENSIS ssp. KURSTAKI#
(various products) — Label rates — 4 — 0
MODE-OF-ACTION GROUP NUMBER[1]: 11A
COMMENTS: This insecticide may be less effective than some broad-spectrum insecticides, but it does not destroy the natural enemies of tomato pests. Treatments applied from egg hatch up to 1st or 2nd instar larva using the egg monitoring program are generally the most effective.

J. TRICHOGRAMMA PRETIOSUM# — at least 100,000/acre — 0 — 0
COMMENTS: Make releases during the fruitworm egg-laying period and when fruit are susceptible. Monitor carefully to determine if additional treatments are necessary. Released parasites are not always effective. Determine the effectiveness of parasite releases within a few days of the release by monitoring fruitworm eggs for parasitism. Host eggs can be placed in the field at the time of the release to help evaluate the effectiveness of the release. If pesticides are applied, *Bacillus thuringiensis* is the only recommended material that will not harm the parasite.

K. PYRETHRIN#
(PyGanic 1.4ECII) — 1–4 pt — 12 — 0
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Short residual material. Buffer to pH 5.5 or lower.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
L. METHOMYL*			
(Lannate 90WSP)	0.5–1 lb	48	1
(Lannate LV)	1.5–3 pt	48	1
MODE-OF-ACTION GROUP NUMBER[1]: 1A			
COMMENTS: This insecticide will also control armyworm and cabbage looper. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies. This insecticide is best used late in the season or during cool months when leafminers are not present. Resistance to this material is a problem in some tomato-growing areas.			
M. ESFENVALERATE*			
(Asana XL)	5.8–9.6 fl oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
COMMENTS: Do not feed or graze livestock on treated vines. Some bleaching or spotting may occur on the foliage of young plants. This does not affect yield or fruit quality. Do not use this product if leafminers are present because it is destructive of their parasites. This material is best used late in the season or during cool months when leafminers are not present. In some areas where tomatoes are grown, resistance to esfenvalerate has been observed. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
N. FENPROPATHRIN*			
(Danitol 2.4EC)	10.66 fl oz	24	3
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
COMMENTS: Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

TOMATO PINWORM (12/13)

Scientific Name: *Keiferia lycopersicella*

DESCRIPTION OF THE PEST

Tomato pinworm occurs throughout southern California and sporadically in some areas of the San Joaquin Valley and coastal growing areas.

Eggs, seldom noticed because of their small size, are usually laid singly on lower surfaces of leaves. Early instars are light colored and appear smooth even when observed with a hand lens; they lack the obvious tubercles and bristles of newly hatched tomato fruitworms or tobacco budworms. Later instars are most often found in fruit; they usually are gray or yellowish withan irregular band of red or purple across each segment. Larvae either pupate in leaf shelters or drop to the ground to pupate. The slender, brown pupa is usually enclosed in a loose silk cocoon with adhering soil or plant debris. Adult moths are small, about ¼ inch (6–8 mm) long, and light gray, peppered with small black flecks.

There can be as many as seven or eight overlapping generations per year.

DAMAGE

This caterpillar feeds on leaves and creates blotch-type mines, but causes most of its damage when it attacks the fruit. Where abundant, the tomato pinworm may seriously damage foliage and infest nearly 100% of the fruit. Larvae normally enter fruit through the calyx, but when populations are high they may enter at any point on the fruit's surface. They make dry burrows and do not penetrate very far into the fruit. When infested fruit is picked, caterpillars may be difficult to detect unless they have been feeding long enough to create small piles of brown, granular frass at the edge of the calyx. Because the pinworm has many generations per season, it becomes more serious as the season advances. The greatest damage occurs where tomatoes are grown from early in the season to late in the fall or in areas where the seasons for early and late tomatoes overlap.

MANAGEMENT

Successful management requires keeping pinworm infestations below damaging levels in the current season, and reducing the overwintering population that will attack later crops. Important management tools are host-free periods, mating disruptants, insecticides, destroying plant residues after harvest, and destroying other solanaceous host plants in the field's vicinity. Careful monitoring can improve management. In the central San Joaquin Valley, tomatoes planted in late winter rarely require treatment for tomato pinworm.

Biological Control

Parasites, including *Apanteles* spp., *Sympiesis stigmatipennis*, and *Parahormius pallidipes*, can be important in controlling pinworm in unsprayed or lightly sprayed fields. Hold infested foliage in cages or bags at room temperature for 2 to 3 weeks. Note the number of parasites that emerge to pupate to determine the percentage of parasitism.

Cultural Control

A host-free period is essential for reducing pinworm populations; the longer the period the better. Destroy residues by burning (where permitted) or plowing-under to help reduce overwintering populations of pinworm. Avoid growing both an early and late-season crop if pinworm is a persistent pest in your area. Shred and disc crop residues immediately after harvest completion, if substantial tomato pinworm populations are present during the first planting and a second crop has been planted in an adjacent field. Crop rotation is not an efficacious management tool unless practiced on an area-wide basis and must also include the removal of solanaceous weeds.

Transplants have been implicated as a potential source of infestation. Check transplants for evidence of pinworm larvae and avoid infested plants.

Organically Acceptable Methods

Biological and cultural control and the use of mating disruptants are acceptable on organically certified produce.

Monitoring and Treatment Decisions

Set out pheromone traps at planting. Use one trap for each 10 acres but no fewer than two traps per field. Distribute traps throughout the field. Check traps and remove any trapped moths twice a week from planting to

harvest. When you begin trapping pinworm adults, start monitoring foliage for larvae. If a mating disruption program is being used, pheromone traps will not catch moths.

To survey the foliage, carefully check for mines and folded leaf shelters on all foliage in several sections of row, each 6 feet long, chosen at random throughout the field; record the average number of larvae per row section. Conduct the first survey as soon as seedlings are well established; continue checking weekly until it is necessary to begin treatments. A provisional guideline is to treat when you count an average of 1 to 2 larvae per row section. Also monitor parasitism percentages.

If pinworm populations reach damaging levels, the narrow-spectrum insecticide abamectin can be used. If broad-spectrum insecticide materials are used, it usually is necessary to continue treating throughout the season until final harvest. The time between treatments depends on population levels. Several materials used to control tomato pinworm kill parasites of *Liriomyza* leafminers, so repeated applications often cause leafminer outbreaks.

Mating disruption

Pheromone mating disruption can be effective in isolated fields and where all tomato fields in an area are treated. In fields surrounded by untreated fields, females may mate in the untreated fields and migrate into treated fields to lay eggs. Where successful, pheromone confusion suppresses pinworm populations without affecting natural controls of pest species. Combine pheromone confusion with a comprehensive program of visual monitoring (pheromone mating disruption will disrupt moths from being attracted to pheromone traps) so you can tell if numbers reach treatment thresholds.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.			
A. MATING DISRUPTANTS#			
(No Mate TPW Spirals)	200–400 spirals/acre (500–1000 spirals/ hectare)	0	0
(Checkmate TPW and others)	200 dispensers/acre (500 dispensers/hectare)		
COMMENTS: Apply according to label instructions with good general distribution throughout field.			
B. ABAMECTIN*			
(Agri-Mek 0.15EC)	16 fl oz	12	7
MODE-OF-ACTION GROUP NUMBER[1]: 6			
COMMENTS: Also effective against leafminers and russet mites; does not harm natural enemies.			
C. METHOXYFENOZIDE			
(Intrepid 2F)	10–16 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 18			
COMMENTS: Low toxicity to natural enemies.			
D. CHLORANTRANILIPROLE			
(Coragen)	3.5–5 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER[1]: 28			
COMMENTS: Can be applied as either a foliar application or in drip chemigation.			
E. EMAMECTIN BENZOATE*			
(Proclaim)	2.4–4.8 oz	12	7
MODE-OF-ACTION GROUP NUMBER[1]: 6			
F. INDOXACARB			
(Avaunt)	3.5 oz	12	3
MODE-OF-ACTION GROUP NUMBER[1]: 22A			
COMMENTS: Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
G. ESFENVALERATE*			
(Asana XL)	5.8–9.6 fl oz	12	1
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
COMMENTS: Do not feed or graze livestock on treated vines. Some bleaching or spotting may occur on the foliage of young plants. This does not affect yield or fruit quality. May cause outbreaks of mites on fresh market tomatoes. Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
H. METHOMYL*			
(Lannate SP)	0.5–1 lb	48	1
(Lannate LV)	1.5–3 pt	48	1
MODE-OF-ACTION GROUP NUMBER[1]: 1A			
COMMENTS: Will also control fruitworm, armyworm, and cabbage looper. Some resistance has been documented. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies. Use only late season or if other management options have been exhausted.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

TOMATO (POTATO) PSYLLID (12/13)

Scientific Name: *Bactericera cockerelli*

DESCRIPTION OF THE PEST

The adult psyllid is a small insect (about 0.12 inches or 3 mm) that resembles a cicada. The adults have white or yellowish markings on the thorax, clear wings, and lines on the abdomen between segments. The tiny eggs are laid on stalks most commonly on the underside of leaves and along leaf margins and are best seen with the use of a hand lens. Initially white, they turn yellow a few hours after they are laid.

Nymphs hatch from eggs in 4 to 15 days and have scalelike flattened, oval, yellowish green to orangish bodies with red eyes and three pairs of short legs. Older nymphs are greenish and fringed with hairs and have wing buds, which make them easy to distinguish from whitefly nymphs; psyllid nymphs will also move if disturbed while whitefly nymphs can not. They develop through five stages (instars) in 2 to 3 weeks before becoming winged adults. Nymphs feed most often on the underside of leaves.

Tomato psyllids have an extensive range of acceptable hosts, but solanaceous plants (tomatoes, potatoes, nightshades) are preferred. Among tomato varieties, it has a preference for the yellow pear tomato.

DAMAGE

Nymphs and perhaps adults inject a toxin while feeding on the leaf that causes death in transplants, stunting, chlorosis and curling of leaves in preflowering plants, and either no fruit production or overproduction of very small, noncommercial-grade fruit in larger plants. These symptoms are collectively known as "'psyllid yellows"' or "vein greening". A bacterium, called *Candidatus* Liberibacter psyllaurous or *Ca.* L. solanacearum, has also been associated with these symptoms in tomatoes.

MANAGEMENT

Monitor for tomato psyllids during the growing season to detect populations that have the potential to stunt plants.

Biological Control

While predators and parasites may attack psyllids, most parasites attack too late in the psyllid life cycle to stop crop loss and biological control does not appear to be a promising control strategy in the field.

Organically Acceptable Methods

Sprays of the Entrust formulation of spinosad are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Yellow sticky cards placed at the field margins near the tops of plants can be used as an indicator of psyllid movement into the field in areas where the pest occurs. If tomato psyllids are caught in the traps, examine foliage of tomato plants on the field margins for eggs and nymphs. If adults are present, a treatment may be warranted.

Applications of imidacloprid (Admire Pro) at planting for thrips and whiteflies provide some control of psyllids. Resistance to imidacloprid, a neonicotinoid, has not been documented in California. However, resistance to neonicotinoids has been observed in Texas. Applications through drip irrigation are most effective, but a liquid application can be shanked about 1 to 2 inches below the seedline (in furrow application) at planting. Do not apply foliar imidacloprid because applications are short lived. Rotate with other insecticides to minimize resistance development.

If psyllids are present in the field, it is very important not to use carbamates (e.g., Sevin-foliar applications, Lannate, Vydate) for the control of other pests as these materials actually promote the development of psyllid populations.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

GROWING SEASON

A.	IMIDACLOPRID			
	(Admire Pro)	7–10.5 fl oz	12	21
	MODE-OF-ACTION GROUP NUMBER[1]: 4A			
	COMMENTS: Do not apply to vegetables grown for seed. Soil applied or through drip at transplant.			
B.	SPINETORAM			
	(Radiant SC)	5–10 fl oz	4	1
	MODE-OF-ACTION GROUP NUMBER[1]: 5			
C.	ABAMECTIN*			
	(Agri-Mek 0.15EC)	8–16 fl oz	12	7
	MODE-OF-ACTION GROUP NUMBER[1]: 6			
D.	SPIROTETRAMAT			
	(Movento)	4–5 fl oz	24	1
	MODE-OF-ACTION GROUP NUMBER[1]: 23			
E.	SPIROMESIFEN			
	(Oberon 2SC)	7–8.5 fl oz	12	1
	MODE-OF-ACTION GROUP NUMBER[1]: 23			
F.	SPINOSAD			
	(Entrust)#	1.25–2.5 oz	4	1
	(Success)	4–8 fl oz	4	1
	MODE-OF-ACTION GROUP NUMBER[1]: 5			

** See label for dilution rates.

Acceptable for use on organically certified produce.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that mustelapse before harvest.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

TOMATO RUSSET MITE (12/13)

Scientific Name: *Aculops lycopersici*

DESCRIPTION OF THE PEST

Russet mites are so small that a 14X hand lens is needed to see them. Because of their size, these mites are rarely noticed until plants are damaged. By this time, there may be hundreds of yellowish, conical-shaped mites on the green leaves immediately above the damaged bronzed leaves.

DAMAGE

Russet mites remove cell contents from leaves, stems, and fruit cells. Usually starting near the ground, infestations of this mite progress up the plant and lower leaves dry out, giving the plant an unhealthy appearance. The color of the stems and leaves frequently becomes greasy bronze or russet colored. If not controlled, this pest can kill plants.

MANAGEMENT

Monitor and treat for these mites if damage is observed. If infestations occur in the same field in successive years, be sure to remove alternate hosts such as nightshades and morningglory.

Organically Acceptable Methods

Mined sulfur dust or sprays are acceptable on organically certified produce.

Monitoring and Treatment Decisions

Look for bronzing on lower leaves and stems, then check damaged leaves and the green leaves immediately above them for mites. Damage is typically first observed when green fruit reaches 1 inch (5 cm); rarely is it first observed after more than 25% of the fruit are ripe. Determine the extent of each infested area in the field by examining leaves and stems for bronzing, and mark the boundaries of the infested areas. Check these areas again in 2 or 3 days to see if they are increasing insize. Immediate treatment is necessary when damage symptoms begin to spread.

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
	The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.			
A.	SULFUR DUST#	Label rates	24	0
	. . . or . . .			
	WETTABLE SULFUR#	Label rates	24	0
	MODE OF ACTION: An inorganic insecticide.			
	COMMENTS: Check with your certifier regarding the suitability of the specific product for use on organically certified crops. Thorough coverage is required; ground application is preferred. Sulfur dust has better coverage. Do not apply when temperatures are in excess of 90°F or during a heavy dew or fog. Do not use if an oil was applied recently or will be in the near future. Avoid drift. Also suppresses powdery mildew.			
B.	ABAMECTIN*			
	(Agri-Mek 0.15EC)	8–16 oz	12	7
	MODE-OF-ACTION GROUP NUMBER[1]: 6			
	COMMENTS: Also effective against leafminers, psyllids, and tomato pinworm; does not harm natural enemies.			

** See label for dilution rates.

‡ Restricted entry interval(R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

Acceptable for use on organically grown produce.

* Permit required from county agricultural commissioner for purchase or use.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

WESTERN YELLOWSTRIPED ARMYWORM (12/13)

Scientific Name: *Spodoptera praefica*

DESCRIPTION OF THE PEST

Larvae of the western yellowstriped armyworm are almost black, with two prominent and many fine, bright yellow stripes on the side. This insect is not a serious pest of tomato every year, but is occasionally destructive. Infestations in tomatoes often originate from moths or caterpillars that migrate from alfalfa fields when the alfalfa is cut or from beans and other crops when they are harvested or dry out.

DAMAGE

This pest feeds on both foliage and fruit. It rarely bores deeply into the fruit, but eats on the surface, causing irregular holes. Infestations are typically sporadic occurring in some years, and when a problem, most severe from July to mid-September.

MANAGEMENT

Monitor yellowstriped armyworms along with other caterpillars when fruit reaches 1 inch. Biological control agents such as *Hyposoter exiguae* may keep populations under control. Treat when the thresholds are exceeded.

Organically Acceptable Methods

Sprays of *Bacillus thuringiensis* ssp. *aizawai* and the Entrust formulation of spinosad are acceptable for use in organically certified crops.

Monitoring and Treatment Decisions

Processing tomatoes

In processing tomatoes, begin sampling fruit when it has reached 1 inch (2.5 cm) or more in diameter. Treatment is not necessary before this size because the damaged fruit will fall from the plant and will be replaced by more fruit. Pick at least 100 fruit at random while walking through the field, being carefulnot to select red fruit when the majority of fruit are green. If damaged fruit are found, determine the amount of damage present and the size and species of the worms (armyworms and fruitworms). Count fruit as damaged if it has any hole deeper than 0.1 inch (2.5 mm), if the hole is contaminated with feces, or if any larvae are present in the fruit. Record observations on a monitoring form *(available online).* The treatment threshold is 3.25% damaged fruit. A sequential sampling technique is available in the online version of this guideline to help reduce the number of samples required to reach a treatment decision. In general, this pest is larger and thus moredifficult to control than beet armyworm.

Fresh market tomatoes

In fresh market tomatoes, begin sampling when fruit appears. Pheromone traps are useful for determining when major flights occur, but not for predicting damage. A 5-minute timed search is useful in determining the need for treatment. On average, if one or more larvae or egg masses are found in 5 minutes, treatments may be justified. Picking large numbers of fruit each week and assessing percent damage may not be economically feasible. Ground applications provide maximum effectiveness of the pesticide.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

A. METHOXYFENOZIDE
(Intrepid 2F) 8–16 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 18
COMMENTS: Research information regarding the efficacy of this material for western yellowstriped armyworm is lacking; used primarily in the San Joaquin Valley for early season infestations. Less toxic to natural enemies than many other choices.

B. METHOMYL*

(Lannate SP) 0.5–1 lb 48 1
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Will also control fruitworm, beet armyworm, and cabbage looper. Some resistance has been documented. Do not use if psyllids are in the field as carbamates tend to promote development of their populations; also if leafminers are present, it may cause outbreaks by destroying their natural enemies.

C. ESFENVALERATE*
(Asana XL) 5.8–9.6 fl oz 12 1
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Some resistance has been documented. Do not use this product if leafminers are present because it is destructive of their parasites. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. SPINOSAD
(Entrust)# 1.25–2.5 fl oz 4 1
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Research regarding efficacy of Entrust formulation for yellowstriped armyworm control is lacking, but efficacy information for the Success formulation suggests it has potential for controlling this species.

E. BACILLUS THURINGIENSIS ssp. AIZAWAI#
(various products) Label rates 4 0
MODE-OF-ACTION GROUP NUMBER[1]: 11A
COMMENTS: This material is also somewhat effective on other caterpillar pests.

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

WHITEFLIES (12/13)

Scientific Names: Sweetpotato whitefly: *Bemisia tabaci* biotype B
Greenhouse whitefly: *Trialeurodes vaporariorum*
Bandedwinged whitefly: *Trialeurodes abutilonia*

DESCRIPTION OF THE PESTS

Several species of whiteflies may infest tomato. Proper identification of sweetpotato whiteflies and greenhouse whiteflies is important because other whitefly species do not cause economic damage in tomato. Use a hand lens to examine both immatures and adults. Whitefly adults are tiny (0.06 inch, 1.5 mm long), yellowish insects with white wings. Sweetpotato whiteflies hold their wings somewhat vertically tilted, or rooflike, over the body; the wings do not meet over the back but have a small space separating them. Greenhouse whitefly adults are very similar in appearance to the sweetpotato whitefly but hold their wings flatter over the back and there is no space between the wings where they meet in the center of the back. Bandedwinged whiteflies, *Trialeurodes abutilonia*, have grayish or brownish bands across their wings.

Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, elongated eggs hatch into a first instar nymphal stage that has legs and antennae and is mobile; first instar nymphs are commonly referred to as "crawlers". Both legs and antennae are lost after the first molt and subsequent nymphal instars remain fixed to the leaf surface and have a scalelike appearance. The last nymphal instar, often called the pupa or the red-eyed nymph, is the easiest to identify. Sweetpotato whitefly pupae are oval, whitish, and soft. The edge of the pupa tapers down to the leaf surface and has few to no long waxy filaments around the edge. In contrast, greenhouse whitefly pupae have many long waxy filament around the edge and the edge is somewhat vertical where it contacts the leaf surface.

Currently sweetpotato whitefly is only a problem of tomatoes grown in southern California and areas of the southern and central San Joaquin Valley. Greenhouse whiteflies are found in all but the lower desert growing areas.

DAMAGE

Both species of whitefly cause damage to leaves by feeding, which causes leaves to yellow and curl, and by the production of honeydew, which causes leaves to appear shiny or blackened (from sooty mold growing on the honeydew). Feeding by sweetpotato whitefly is especially damaging because it also causes fruit to ripen unevenly.

In recent years, the greenhouse whitefly has been found to be the vector of tomato infectious chlorosis virus, a virus capable of causing heavy losses in the production of fresh-market and greenhouse tomatoes.

Bemisia species of whiteflies transmit gemini viruses such as that cause TOMATO YELLOW LEAF CURL, which has recently been found in the Imperial Valley and Coachella Valley. The spread of this virus in the state is a major threat to tomato production. To prevent the spread of *Tomato yellow leaf curl virus* into other areas of California, do not bring transplants into California from out-of-state or move transplants or other *Bemisia*-infested hosts from an area that is known to be infested with the disease to uninfested areas. Use only virus-free tomato transplants grown and shipped from the Imperial Valley, which are monitored by CDFA and the county agricultural commissioner's office.

MANAGEMENT

An integrated pest management program for whiteflies includes following good cultural practices, such as host-free periods, conserving natural enemies, routinely monitoring fields for trouble spots, and using pesticides only when necessary.

Biological Control

Several wasps, including species in the *Encarsia* and *Eretmocerus* genera, parasitize whiteflies. Whitefly nymphs are also preyed upon by bigeyed bugs, lacewing larvae, and lady beetle larvae. Sweetpotato whitefly is an introduced pest that has escaped its natural enemies. Some indigenous native parasites and predators do attack it, but do not keep it below damaging numbers. The parasitic wasp, *Encarsia formosa,* has been used successfully to control greenhouse whitefly in greenhouses or protected crop situations elsewhere in the world where tomatoes are more commonly grown in this manner.

Cultural Control

The best control for whiteflies is to maximize the distance and time interval between host crops.

- When possible, plant tomatoes at least one-half mile upwind from key sweetpotato whitefly hosts such as melons, cole crops, and cotton.
- Maintain good sanitation in areas of winter and spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in noncrop areas including head rows (headland areas) and fallow fields.
- Harvest alfalfa on as short a schedule as possible.
- Allow the maximum time between harvest andsubsequent planting of sweetpotato whitefly host crops.
- Grow vegetables and melons in the shortest time-span possible.

Adult sweetpotato whiteflies are repelled by silver- or aluminum-colored mulches. Place reflective polyethylene mulches on planting beds before seeding or transplanting to significantly reduce rate of colonization by whiteflies and delay the buildup of damaging numbers of whiteflies by 4 to 6 weeks. This delay in infestation can be especially important if virus transmission is a major concern. The mulches lose their effectiveness when more than 60% of the surface is covered by foliage. Therefore, they are effective only for the first few weeks after seedling emergence or transplanting of either spring or fall tomatoes.

Greenhouse whiteflies are often induced by applications of broad-spectrum pesticides. Avoid such materials early in the season.

Organically Acceptable Methods

Cultural and biological control as well as sprays of insecticidal soaps and oil plus azadirachtin are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Routinely check field margins for whiteflies; these areas are usually infested first. Be especially alert forthe rapid migration of whiteflies when nearby host crops are in decline. During these critical periods, check fields twice weekly. Yellow sticky traps may be useful in detecting initial whitefly migrations into fields.

Allow beneficials an opportunity to control light whitefly infestations. If higher populations are present at the field margins than the field centers, then treat only the field margins. This approach will reduce treatment costs and help preserve beneficials in the field. The treatment threshold for sweetpotato whitefly is about 4 adults per leaf in a random 30-leaf sample of healthy leaves. Thresholds have not yet been established for greenhouse whitefly.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.

AT PLANTING OR TRANSPLANTING

A.	IMIDACLOPRID (Admire Pro)	7–10.5 fl oz	12	21
	MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Effective against all whitefly species, but it is suggested here to target sweetpotato whitefly. Do not apply to vegetables grown for seed. Soil applied or through drip at transplant.			
B.	DINOTEFURAN (Venom)	5–6 oz	12	21
	MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Soil application. Not for use on varieties with fruit less than 2 inches (e.g., cherry or grape tomatoes) or for use on vegetables grown for seed.			

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
C. ACETAMIPRID (Assail) MODE-OF-ACTION GROUP NUMBER[1]: 4A	0.6–1.7 fl oz	12	7
DURING GROWING SEASON			
A. SPIROTETRAMAT (Movento) MODE-OF-ACTION GROUP NUMBER[1]: 23	4–5 fl oz	24	1
B. SPIROMESIFEN (Oberon 2SC) MODE-OF-ACTION GROUP NUMBER[1]: 23 COMMENTS: Apply early to help prevent virus transmission if that is a concern.	7–8.5 fl oz	12	1
C. BUPROFEZIN (Courier SC) MODE-OF-ACTION GROUP NUMBER[1]: 16 COMMENTS: An insect growth regulator.	9–13.6 fl oz	12	1
D. PYRIPROXYFEN (Knack) MODE-OF-ACTION GROUP NUMBER[1]: 7C COMMENTS: An insectgrowth regulator. Effective against immature whiteflies only. Repeated tank mixes of this product with orthene may cause leafminer outbreaks.	8–10 fl oz	12	14
E. ENDOSULFAN* (Thionex 3EC) MODE-OF-ACTION GROUP NUMBER[1]: 2A COMMENTS: Apply in 100 to 200 gallons water/acre. Ground application recommended. Availability in many areas is limited because of label restrictions for fields near waterways. Do not use after July 31, 2015.	0.66 qt/100 gal	96	4
F. BIFENTHRIN* (Capture 2EC-CAL) MODE-OF-ACTION GROUP NUMBER[1]: 3A	2.1–5.2 oz	12	1
G. FENPROPATHRIN* (Danitol 2.4EC) MODE-OF-ACTION GROUP NUMBER[1]: 3A *. . . PLUS . . .* MALATHION 8 MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: Do not use a Group number 3 insecticide if leafminers are present because it is destructive of their parasites. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i. Do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	7–10.66 fl oz 1.5 pt	24 12	3 1
H. INSECTICIDAL SOAP# (M-Pede) MODE OF ACTION: A contact insecticide with smothering and barrier effects. COMMENTS: Thorough coverage, including lower sides of leaves, is essential for good control. Ground applications provide better coverage than aerial ones. Using hollow-cone nozzles or air-assist sprayers improves canopy penetration. Additional treatments may be necessary.	Label rates	12	0

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
I.	ROSEMARY OIL + PEPPERMINT OIL#			
	(Ecotrol EC)	3 pt	0	0
	MODE OF ACTION: Contact including smothering and barrier effects.			
	. . . PLUS . . .			
	AZADIRACHTIN#			
	(Neemix 4.5)	7 oz	4	0
	MODE-OF-ACTION GROUP NUMBER[1]: un			
	COMMENTS: Thorough coverage, including lower sides of leaves, is essential for good control. Ground applications provide better coverage than aerial ones. Using hollow-cone nozzles or air-assist sprayers improves canopy penetration. Additional treatments may be necessary. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank-mixing products that contain the same a.i. Do not use if sulfur was applied recently or will be in the near future.			
J.	OXAMYL*			
	(Vydate L)	2–4 pt	48	3
	MODE-OF-ACTION GROUP NUMBER[1]: 1A			
	COMMENTS: Apply in sufficient water to obtain uniform coverage of foliage. Use low rate for light infestations and high rate for severe infestations. This insecticide works best in combination with endosulfan for the control of whiteflies.			

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown produce.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers ("un"=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

WIREWORMS (12/13)

Scientific Name: Sugarbeet wireworm: *Limonius californicus* and other *Limonius* spp.

DESCRIPTION OF THE PESTS

Wireworms are shiny, slender, cylindrical, hard-bodied, wirelike, yellow-to-brown larvae found at all times of the year and in almost any kind of soil; the larval (or wireworm) stageof this beetle may last several years. Adults of these larvae are known as click beetles.

DAMAGE

Wireworm larvae injure crops by devouring seeds in the soil, thus preventing seedlings from emerging; by cutting off small, underground stems and roots; and by boring into larger stems and roots of transplants.

MANAGEMENT

The presence of wireworm larvae can be monitored by burying carrot or potato pieces on the surface to 3 inches deep into the soil at several locations throughout the field during seeding. Check weekly for holes in the carrot or potato from wireworm feeding. No thresholds have been developed.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
The following materials are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label ofthe product being used.			
PREPLANT			
A. DIAZINON* (Diazinon AG500)	3–4 qt	24	NA
MODE-OF-ACTION GROUP NUMBER[1]: 4A			
COMMENTS: A soil application; may also be applied via chemigation. Apply immediately after transplanting when conditions suggest wireworms could be a problem.			
AT PLANTING, TRANSPLANTING, AND POSTPLANT			
A. CLOTHIANIDIN (Belay)	9–12 fl oz	12	NA
MODE-OF-ACTION GROUP NUMBER[1]: 4A			
COMMENTS: A soil application at planting or transplanting.			
B. IMIDACLOPRID (Admire Pro)	7–10.5 fl oz	12	21
MODE-OF-ACTION GROUP NUMBER[1]: 4A			
COMMENTS: A soil application; may also be applied via chemigation. Apply immediately after transplanting when conditions suggest wireworms could be a problem.			
C. ACETAMIPRID (Assail)	0.6–1.7 fl oz	12	7
MODE-OF-ACTION GROUP NUMBER[1]: 4A			

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

** See label for dilution rates.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safelyentered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

* Permit required from county agricultural commissioner for purchase or use.

NA Not applicable.

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at http://www.irac-online.org/.

Diseases

(Section reviewed 12/13)

ALFALFA MOSAIC (12/13)

Pathogen: *Alfalfa mosaic virus*

SYMPTOMS

Typical leaf symptoms on plants with alfalfa mosaic include bright yellow blotches with some mottle. Leaves eventually develop a bronze discoloration. Internally, phloem tissue becomes necrotic, including the phloem in the roots. The disease usually causes plant death. One of the most striking symptoms is the necrotic rings and spots on the fruit. Some fruit may develop a solid brown necrosis over the surface.

COMMENTS ON THE DISEASE

Alfalfa mosaic virus infections of tomatoes generally occur when tomatoes are grown near alfalfa. The disease is most prevalent a few rows into a tomato field near alfalfa. *Alfalfa mosaic virus* is seedborne in alfalfa and most alfalfa fields are infected and provide a good inoculum source. The virus is transmitted by several species of aphids; spread from alfalfa to surrounding crops is common. Aphids transmit *Alfalfa mosaic virus* only when probing leaf tissues and not during feeding on plants. Once an aphid acquires *Alfalfa mosaic virus*, it retains the ability to transmit the virus for only a short period of time (minutes to hours) and spread is localized.

MANAGEMENT

Outbreaks of virus diseases are unpredictable from year to year and for various geographic locations. Use of silver reflective mulches may delay the infection by aphid-borne viruses and reduce the incidence and severity of thesediseases by repelling aphids that transmit them. Place reflective polyethylene mulches on planting beds before seeding or transplanting to reduce aphid landing and virus transmission. The mulches lose their effectiveness when more than 60% of the surfaceis covered by tomato plant foliage.

In general alfalfa mosaic is nota major problem of California tomatoes, although it occurs in localized areas each year. The best way to control alfalfa mosaic is to avoid planting tomatoes near alfalfa fields and to avoid use of insectary plantings that contain alfalfa near tomato fields. No resistance to this virus is currently available in commercial tomato cultivars. No effective chemical control strategies are currently available. Insecticides aimed at controlling the aphid vectors are ineffective.

ALTERNARIA STEM CANKER (12/13)

Pathogen: *Alternaria alternata* f. sp. *lycopersici*

SYMPTOMS

Symptoms of Alternaria stem canker appear on stems, leaves, and fruit. Dark brown to black cankers withconcentric zonation occur on stems near the soil line or aboveground. Cankers enlarge, girdle the stem before harvest, and kill the plants. Vascular tissue about 2 inches above and below the cankers exhibit brown streaks. Dark brown to black areas of dead tissue between leaf veins are caused by a toxin produced by the fungus. Dark brown sunken lesions with characteristic concentric rings develop on green fruit either on plants or during postharvest transit of ripening fruit.

COMMENTS ON THE DISEASE

Alternaria stem canker is primarily a problem of coastal-grown tomatoes in California although the disease occurs occasionally in other areas of the state in fields planted with infested transplants. The fungus survives on infected tomato debris. Infection occurs when airborne spores land on tomato plants or when plants come in contact with infested soil. Free water is necessary for spore germination and infection. Disease spread is favored by rains, dew, and overhead irrigation. Symptoms develop 7 to 10 days after inoculation and develop most rapidly at temperatures around 77°F (25°C).

MANAGEMENT

Many tomato cultivars with high levels of resistance to Alternaria stem canker are available. Fungicides that control blackmold are effective against Alternaria stem canker.

ANTHRACNOSE (12/13)

Pathogen: *Colletotrichum coccodes*

SYMPTOMS

Anthracnose of tomatoes is primarily a disease of ripe and overripe fruit. Depressed, circular lesions about 0.5 inch (1.2 cm) in diameter appear on ripe fruit. With age the lesions become tan and dotted with small black specks (microsclerotia). Dark, needle-like spines, called setae, surround the microsclerotia and acervuli, cushion-shaped fruiting bodies that erupt through the plant tissue. During moist weather, masses of salmon-colored sausage-shaped spores may form on the lesion surface.

Infection may also occur on stems, leaves, and roots. Root infections (called black dot root rot) become evident when fruit begin to ripen. Root lesions are brown and dotted with microsclerotia. The cortex of infected roots is often completely rotted.

COMMENTS ON THE DISEASE

The fungus is a weak parasite and generally infects ripe or overripe fruit and roots of mature plants. In California, anthracnose on fruit occurs infrequently because of its dry weather. Root rot, however, is not uncommon, especially where tomatoes are grown year after year in the same soils. The effect of black dot root rot on yields is not known.

MANAGEMENT

Rotate with nonsolanaceous crops at least every other year. Avoid sprinkler irrigation when fruit begin to ripen. Fungicides are generally not required. Fungicides for blackmold are effective against anthracnose fruit rot.

BACTERIAL CANKER (12/13)

Pathogen: *Clavibacter michiganensis* pv. *michiganensis*

SYMPTOMS

There are usually no symptoms of bacterial canker on seedlings; however, on young plants symptoms consist of poor growth and temporary wilting of branches. Lower leaves yellow and shrivel, but symptoms may not show until flowering. On mature plants there are two kinds of symptoms. One kind is from systemic infections (i.e., the bacteria enter the vasculature and invade much of the plant) and the other resulting from secondary infections (i.e., the bacteria cause local infections of leaves, stem, and fruit).

In systemic infections of mature plants, leaflets of the oldest leaves curl, yellow, wilt, and finally turn brown and collapse (known as firing). Sometimes, one side of a leaf is affected. Plants grow poorly and wilt. Pith of stems becomes yellow and later reddish brown, especially at the nodes, and has a mealy appearance. The pith may later become somewhat hollow. In advanced infections, cankers may or may not form at the nodes. Light and later dark streaks may develop on stems. Branches break off easily. Plants may die.

In secondary infections, infection of the marginsof leaves is common. Lesions are dark brown to almost black. Round to irregular spotting of leaves also occurs. Fruit may be spotted, especially near calyx.

On fruit bacterial canker symptoms appear as yellow to brown spots, slightly raised, surrounded by a persistent white halo (""bird's eye spot""). Spots are usually about 0.125 inch (3 mm) in diameter. Vascular tissue under the calyx scar, leading to seeds that may be brown.

COMMENTS ON THE DISEASE

In California, the source of the pathogen is probably seed and transplants, although local contamination within greenhouses is a potential source. In California, the pathogen only overwinters in the soil when the previous crop residue is not thoroughly incorporated and does not decompose. In colder climates, the bacterium may overwinter on undecomposed plant residue.

Tomato is the most important host of the pathogen. Several nightshades, including perennial nightshade (*Solanum douglasii*), black nightshade (*S. nigrum*), and *S. triflorum*, are naturally infected. It is not known how long the bacterium can persist on nightshade. Pepper and eggplant can be artificially inoculated, but they are probably not important in the epidemiology of the disease on tomato.

In California, economic losses in direct-seeded fields are very uncommon. During unusually wet weather, however, secondary spread from frequent vine-training,cultivation, or other operations may cause extensive leaf loss. Canker probably occurs at a low incidence in many direct-seeded fields but almost always goes unnoticed.

Seed contamination with only a few bacterial cells, apparently below the level of detection, can result in relatively high numbers of infected transplants. For that reason, certified seed reduces the chances of infections, but is no guarantee of contaminated-free seed. A seed lot contaminated with very few infested seeds can cause serious problems in a greenhouse.

When the seed germinates, the bacteria enter the seedling through small wounds in the cotyledon, probably through broken trichomes. The bacteria move systemically through the xylem from which it invades the phloem, pith, and cortex. In a highly conducive environment, like a greenhouse, bacteria on the surface of infected plants are then splashed to surrounding plants during overhead irrigation. This kind of spread accounts for the occurrence of groups of plants or trays in the greenhouse and subsequent rows of infected transplants in the field. During planting, which invariably causes wounds, transplants may also be infected after an infected plant is handled, especially if the plants are wet.

Secondary spread occurs in splashing water, on contaminated equipment, during clipping, cultivation, vine-training operations, and other activities. In the field, such spread usually results in local infections (i.e., leaf, stem, and fruit spots). In the greenhouse, these sources can lead to local and systemic infections.

MANAGEMENT

In the field, the pathogen will survive indefinitely in tomato tissue. Once that tissue has decomposed in the ground, however, the bacteria will die because they are not soil inhabitants. Thus, it is very important to turn

under infected plant residue at the end of the season. Once that residue decomposes, the bacteria will die and the field does not pose a problem for subsequent plantings. It is prudent, however, to rotate to another crop for at least one season to assure that the tomato residue is completely gone.

In research trials, bacteria have survived as long as 10 months on contaminated wooden stakes. Hence, in the greenhouse it may be extremely important to disinfest the surface of benches and equipment to prevent spread to subsequent trays of transplants. In fields of more mature plants, disinfesting equipment is not as critical because any spread to other plants would probably result in local, and not systemic, infections. It is prudent, however, to wash equipment that has been through a heavily infested field. Surface disinfectants include bleach solutions (0.5 to 1% calcium hypochlorite) and Physan, among other products.

Planting clean transplants is the most important control measure.

- Vigilantly monitor seed fields and implement strict quality control measures. Assay seed for detectable levels of contamination and discard lots if the bacterium is found. Soak all seed in 130°F water for 25 minutes.
- In the greenhouse, steam potting mix and flats; flats may also be washed with a 1% solution of calcium hypochlorite. Empty greenhouses between crops of transplants to allow time to disinfest benches and irrigation hoses. Overhead water pressure should be low to prevent wounding during irrigation.

In the field, special measures may have to be taken once canker has been identified.

- Do not work fields when the foliage is wet. Frequent field operations at the wrong time can result in spread of the disease throughout the entire field. Unless the number of infected plants is small, it may do more harm than good to try to remove the symptomatic plants.
- Copper applications offer limited benefits because systemic infections cannot be affected and localized infections (the most probable scenario if other precautions are taken) pose a small economic threat.
- During wet weather, however, bactericides may be justified.
- At the season's end, incorporate all plant tissue. Tissue that remains on the surface and doesn't decompose is a real risk to subsequent tomato crops. Once the tomato residue decomposes, however, canker is no longer a threat.
- To be absolutely certain that the bacterium has been eliminated from the field, rotate out of tomatoes for at least one year.

BACTERIAL SPECK (12/13)

Pathogen: *Pseudomonas syringae* pv. *tomato*

SYMPTOMS

Bacterial speck appears as dark brown to black lesions of various sizes and shapes on leaves, fruit, and stems. Tissue adjacent to the lesions is initially yellow. Leaf lesions are frequently concentrated near margins, causing extensive marginal necrosis (tissue death). Lesions on immature fruit are slightly raised and small, varying in size from tiny flecks to 0.125 inch (3 mm) in diameter and cause raised black spots on mature fruit. Fruit lesions are superficial, seldom penetrating more than a few cells deep.

COMMENTS ON THE DISEASE

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

MANAGEMENT

Cultural controls and copper spray generally provide adequate control of bacterial speck in early planting.

Cultural Control

- Delay planting in spring to avoid exposing tomatoes to cool wet conditions that favor disease development.
- When the disease appears, change from overhead to furrow irrigation.
- Do not plant tomatoes in a field previously planted to tomatoes that developed the disease; instead rotate with a nonhost crop such as small grains or corn.

There are two races in California: Race 0 and Race 1. Many varieties are resistant against Race 0 but none currently possess resistance against Race 1, which is the predominant race throughout the state.

Organically Acceptable Methods

Cultural control and some copper formulations are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Copper-containing bactericides provide partial disease control. Timing is critical. Apply before rainfall and repeat at 10- to 14-day intervals when cool and moist conditions prevail. Copper is strictly a protectant and must be applied before an infection period occurs. One or two treatments are usually enough to protect tomatoes during the most susceptible stages of growth. Spraying can stop when temperatures move into the 90°F range.

Resistance or partial resistance to copper is common. This is somewhat overcome by combining copper with mancozeb.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management,honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

A.	COPPER HYDROXIDE#			
	(Kocide 3000)	0.75–1.75 lb	48	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)			
	COMMENTS: Not all copper compounds are approved for use in organic production; be sure to check individual products.			
B.	COPPER HYDROXIDE#			
	(Kocide 3000)	0.75–1.75 lb	48	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)			
	. . . PLUS . . .			
	MANCOZEB			
	(Dithane M-45)	2 lb	24	5
	(Dithane F-45 Rainshield)	1.6 qt	24	5
	(Penncozeb 75DF)	1–1.5 lb	24	5
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)			
	COMMENTS: The addition of mancozeb increases the efficacy of copper. Check with your processor concerning allowed materials and rates. Be sure to follow label directions on all products when making a tank mix; the most restrictive label precautions and limitations must be followed.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

BACTERIAL SPOT (12/13)

Pathogen: *Xanthomonas campestris* pv. *vesicatoria*

SYMPTOMS

Bacterial spot develops on seedlings and mature plants. On seedlings, infections may cause severe defoliation. On older plants, infections occur primarily on older leaves and appear as water-soaked areas. Leaf spots turn from yellow or light green to black or dark brown. Older spots are black, slightly raised, superficial and measure up to 0.3 inch (7.5 mm) in diameter. Larger leaf blotches may also occur, especially on the margins of leaves. Symptoms on immature fruit are at first slightly sunken and surrounded by a water-soaked halo, which soon disappears. Fruit spots enlarge, turn brown, and become scabby.

COMMENTS ON THE DISEASE

The bacterial spot bacterium persists from one season to the next in cropdebris, on volunteer tomatoes, and on weed hosts such as nightshade and groundcherry. The bacterium is seedborne and can occur within the seed and on the seed surface. The pathogen is spread with the seed or on transplants. Secondary spread within a field occurs by splashing water from sprinkler irrigation or rain. Infection is favored by high relative humidity and free moisture on the plant. Symptoms develop rapidly at temperatures of 68°F (20°C) and above. Night temperatures of 61°F (16°C) or below suppress disease development regardless of day temperatures. Some pathogen strains are virulent on either tomato or pepper and some may be virulent on both.

MANAGEMENT

Cultural practices and preventive sprays of copper help to manage bacterial spot.

Cultural Control

Bacterial spot occurs commonly in tomatoes throughout California. Using pathogen-free seed and disease-free transplants, when possible, is the best way to avoid bacterial spot on tomato. Avoiding sprinkler irrigation and cull piles near greenhouse or field operations, and rotating with a nonhost crop also helps control the disease.

Organically Acceptable Methods

Cultural controls and some copper formulations are acceptable for use on organically certified produce.

Monitoring and Treatment Decisions

Copper-containing bactericides provide partial disease control. Apply at first sign of diseaseand repeat at 10- to 14-day intervals when warm, moist conditions prevail. Copper is strictly a protectant and must be applied before an infection period occurs.

Resistance to copper has been observed, but can be somewhat overcome by combining copper with mancozeb.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management,honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.			
A. COPPER HYDROXIDE#			
(Kocide 3000)	0.75–1.75 lb	48	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)			
COMMENTS: Not all copper compounds are approved for use in organic production; be sure to check individual products.			
B. COPPER HYDROXIDE#			
(Kocide 3000)	0.75–1.75 lb	48	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)			
. . . PLUS . . .			
MANCOZEB			
(Dithane M-45)	2 lb	24	5
(Dithane F-45 Rainshield)	1.6 qt	24	5
(Penncozeb 75DF)	1–1.5 lb	24	5
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)			
COMMENTS: The addition of mancozeb increases the efficacy of copper. Check with your processor concerning allowed materials and rates. Be sure to follow label directions on all products when making a tank mix; the most restrictive label precautions and limitations must be followed.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

BLACKMOLD (12/13)

Pathogen: *Alternaria alternata*

SYMPTOMS

Blackmold is characterized by obvious lesions that appear on the surface of ripe fruit. Lesions are light to dark brown and vary from small flecks affecting only epidermal tissue to large, more or less circular, sunken lesions with decay extending into the carpel wall and often into the seed locule. During warm, humid weather the fungus may sporulate to form a black, velvetlike layer on the surface of the sunken lesions.

COMMENTS ON THE DISEASE

Blackmold is a disease of ripe tomato fruit that appears in the field after rain or dew. Disease incidence is higher with increased late-season rain; it is most common in late-season processing tomatoes. Fungal spores need 3 to 5 hours of wetness to germinate. After germination they can infect fruit by directly penetrating the epidermis. A crop can be heavily damaged within 4 to 5 days following a period of rain and high humidity. The fungus also readily colonizes any wounds on the fruit, including sunburned areas.

MANAGEMENT

Cultural practices help reduce the damage potential of the blackmold fungus but preventive treatments may be needed for control in areas where it poses a continual problem.

Cultural Control

- Avoid overhead irrigation late in the season and keep beds dry.
- Delays in harvest increase the chance of exposure to rain or dew and the incidence of blackmold. Begin harvest as soon as fruit ripens.

Cultural practices that encourage dense leaf canopies and the selection of varieties that develop and retain a heavy canopy, may aid in preventing blackmold by protecting fruit from dew. However, a dense canopy also retains high humidity that favors other fruit molds such as gray mold.

Organically Acceptable Methods

Cultural control is acceptable for use on organically certified produce.

Treatment Decisions

Treatments are most likely necessary in late-harvest fields, in rainy years, or if the fruit is damaged. Apply the first treatment 4 to 6 weeks before anticipated harvest. Two applications may be necessary if harvest is anticipated after mid-September. Check with tomato processor representatives concerning allowed fungicides and rates.

Common name (example trade name)	Amount per acre**	R.E.I+ (hours)	P.H.I.‡ (days)

When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management,honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

A.	CHLOROTHALONIL (Bravo Weather Stik, generics) MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)	2–2.75 pt	12	0
B.	AZOXYSTROBIN (Quadris F) MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11) COMMENTS: Apply on a 7- to 14-day interval; make no more than 3 sequential applications before alternating with a fungicide that has a different mode of action. Do not alternate or tank mix with fungicides to which resistance has developed in the pathogen population.	5–6 fl oz	4	0
C.	AZOXYSTROBIN + DIFENOCONAZOLE (Quadris Top) MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11) + Dimethylation inhibitor (3)	8 fl oz	12	0

Common name (example trade name)	Amount per acre**	R.E.I+ (hours)	P.H.I.‡ (days)
D. PENTHIOPYRAD			
(Fontelis)	See label	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate dehydrogenase inhibitor (7)			
E. MANCOZEB			
(Dithane M-45)	1.5–2 lb	24	5
(Dithane F-45 Rainshield)	1.2–1.6 qt	24	5
(Penncozeb 75DF)	1.5–2 lb	24	5
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)			
F. PYRACLOSTROBIN			
(Cabrio EG)	8–12 oz	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)			
COMMENTS: Apply at 7- to 14-day intervals; use higher rate and shorter interval when disease pressure is high.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

CORKY ROOT ROT (12/13)

Pathogen: *Pyrenochaeta lycopersici*

SYMPTOMS

Infected roots of plants with corky root rot are distinctly corky. Extensive brown lesions, often arranged in bands with lengthwise cracking of the cortex, develop on the larger roots. The tips of infected older roots are pinched off. Small feeder roots may be completely decayed. Infected plants are stunted and slow-growing. Branches on mature plants may die back from the tips.

COMMENTS ON THE DISEASE

The fungus survives for long periods as microsclerotia. Potential alternate hosts include cucurbits, peppers, safflower, and solanaceous weeds such as on nightshades. Corky root is generally a problem in early plantings under cool conditions. Disease development is optimal at 60° to 68°F (15.5–20°C). Corky root usually does not kill plants, but may reduce yields.

MANAGEMENT

Cultural practices, or soil fumigation on fields with a history of corky root rot, will help to minimize problems from this disease.

Cultural Control

- Plant when soils are warm in spring.
- Avoid consecutive crops of tomatoes.
- Although not extensively tested in California, soil solarization has been used to control corky root rot in other areas of the world.
- Rotate with nonhost crops.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop.

Treatment Decisions

In fields with a history of corky root rot, a preplant treatment with metam sodium may reduce disease in a subsequent tomato crop.

Common name (example trade name)	Amount per acre**	R.E.I‡ (hours)	P.H.I‡ (days)

When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management,honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

PREPLANT

A.	METAM SODIUM*			
	(Vapam HL)	50–75 gal	See label	NA
	(Metam CLR 42%, etc.)	50–75 gal	See label	NA
	COMMENTS: Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing.

* Permit required from county agricultural commissioner for purchase or use.

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NA Not applicable.

CURLY TOP (12/13)

Pathogen: *Beet curly top virus* in the geminivirus group

SYMPTOMS

Plants with curly top are stunted because growth ceases. Plants turn yellow to bronze with purple-tinged leaves. Plants become stiff and soon die. Green fruit turns red, regardless of age.

COMMENTS ON THE DISEASE

Beet curly top virus is only spread from plant-to-plant by the beet leafhopper, *Circulifer tenellus*. The virus and the beet leafhopper have very wide host ranges. Leafhoppers overwinter in the foothills bordering the Central Valley, migrating down into the Valley in late spring. Occurrence of the curly top disease is spreading; in some years it has caused almost complete crop loss in individual fields near the foothills.

Beet curly top virus is limited to the phloem, the food-conducting tissues of the plant, and the leafhopper must feed on the phloem in order to acquire and inoculate the virus to plants. Once acquired by the leafhopper, beet curly top virus is carried for the rest of the leafhopper's life, and thus long distance spread is common. Infected plants are often widely scattered in a field; field margins are especially vulnerable because leafhoppers like tofeed on plants that border bare soil areas.

MANAGEMENT

Dense stands of tomatoes apparently discourages visitation by leafhoppers. There is no genetic resistance in tomatoes to beet curly top virus. A statewide control program designedto control the beet leafhopper is practiced annually by spraying foothill areas where leafhoppers are congregated.

DAMPING-OFF (12/13)

Pathogens: *Phytophthora*, *Pythium*, and *Rhizoctonia* spp.

SYMPTOMS

Seedlings affected by damping-off fail to emerge or fall over and die soon after emergence. Stems usually have a dark, shriveled portion at the soil line. Damping-off is generally limited to areas where drainage is poor or where soil is compacted, but whole fields can be affected, especially in early plantings exposed to rain.

COMMENTS ON THE DISEASE

"Damping-off" is a general term for the death of seedlings, either before or after emergence, under damp conditions. It is mainly an early season problem, causing the greatest losses in cool, wet soils.

Fungi that cause damping-off occur in all soils where tomatoes are grown and they infect tomatoes when the soil is wet. Infection is most common under cool conditions, although both *Phytophthora* and *Rhizoctonia* can also infect seedlings in warmer soils. Once tomato seedlings reach the 2- or 3-leaf stage, they are no longer susceptible to infection by *Pythium* or *Rhizoctonia*; however, *Phytophthora* can infect tomato plants at any stage. Damping-off due to *Pythium* may increase where green manures such as volunteer grain are worked into the soil just before planting. Damping-off does not necessarily carry over from one season to another in the same places but appears only when and where conditions favor infection.

MANAGEMENT

Proper field and seedbed preparation and good water management significantly reduce losses from damping-off. By using sprinklers for germination, you keep better control of water and lessen the chance of infection. If possible, avoid planting when the soil is cool; seeds germinate faster and seedlings are more vigorous when the soil is warm, so they are less likely to be damaged. The use of fungicide seed treatments can help prevent damping-off. When seedling loss is extensive, replanting may be necessary.

EARLY BLIGHT (12/13)

Pathogen: *Alternaria solani*

SYMPTOMS

Plants infected with early blight develop small black or brown spots, usually about 0.25 to 0.5 inch (6–12 mm) in diameter, on leaves, stems, and fruit. Leaf spots are leathery and often have a concentric ring pattern. They usually appear on older leaves first. Spots onfruit are sunken, dry, and may also have a concentric pattern; frequently they occur near the calyx end of the fruit.

COMMENTS ON THE DISEASE

Early blight is not common in California; it occurs in coastal areas and mainly affects tomatoes exposed to rain. Damage can occur if conditions remain cool and humid for several days after a rain. The early blight fungus survives in the soil on residue of infected tomatoes, potatoes, and nightshade weeds. The fungus is spread by spores (oval shaped with a long beak) carried by wind or splashed in water. Germination of spores and infection require free moisture. Disease development stops in dry, hot weather.

MANAGEMENT

Most California varieties are susceptible to early blight, but treatment is rarely needed because its occurrence is uncommon.

- Destroy nightshades and volunteer tomato and potato plants.
- Proper crop rotation is important to ensure infected plant debris decomposes.
- Apply a fungicide when environmental conditions are favorable and the first sign of disease becomes apparent.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management, honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.			
A. CHLOROTHALONIL			
(Bravo Weather Stik)	1.5–2 pt	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)			
B. MANCOZEB			
(Dithane M-45)	1.5–2 lb	24	5
(Dithane F-45 Rainshield)	1.2–1.6 qt	24	5
(Penncozeb 75DF)	1.5–2 lb	24	5
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)			
C. FIXED COPPER#	Label rates	—	—
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)			
COMMENTS: Not all copper compounds are approved for use in organic production; be sure to check individual products.			
D. BACILLUS SUBTILIS#			
(Serenade Max)	1–3 lb	4	0
MODE OF ACTION: A biological fungicide.			
COMMENTS: For suppression begin applications when plants are 4 to 6 inches tall. Repeat on a 5-to-7-day interval or as needed.			

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment untilthe treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action Group number.

Acceptable for use on organically grown produce.

FUSARIUM CROWN AND ROOT ROT (12/13)

Pathogen: *Fusarium oxysporum* f. sp. *radicis-lycopersici*

SYMPTOMS

Foliar symptoms on plants with Fusarium crown and root rot include yellowing along the margin of the oldest leaves, followed by necrosis. Dry brown lesions develop in the cortex of the tap or main lateral roots. A necrotic lesion may also develop on the surface of the stem from the soil line to 4 to 12 inches above it. Internally, a reddish brown or chocolate brown discoloration extends no more than 6 to 12 inches above the soil line. Infected plants may be stunted and wilted, and older plants may die.

COMMENTS ON THE DISEASE

Fusarium crown and root rot can occur in any of the California tomato-growing regions; in the Central Valley, it has recently become more common and widespread. The disease occasionally causes serious problems in greenhouses. In the field it causes economic damage in the Sacramento Valley, upper San Joaquin Valley, and near the coast, especially in Southern California. The fungus overwinters and survives for many years in the soil as spores. Long distance spread is by transplants and in soil on farm machinery. Spores are airborne in greenhouses. The disease is favored by cool soil temperatures. The host range of the pathogen includes some legumes, cucurbits, other solanaceous plants, and more.

MANAGEMENT

In greenhouses, plant in steamed soil. In the field, planting disease-free transplants is the only recommended management practice for this disease.

FUSARIUM FOOT ROT (12/13)

Pathogen: *Fusarium solani* f. sp. *eumartii*

SYMPTOMS

Fusarium foot rot causes varying degrees of interveinal chlorosis and necrotic spotting on young foliage. Foliar symptoms may be similar to certain viruses (tomato spotted wilt or alfalfa mosaic). Flowers are often necrotic. Aboveground symptoms may be restricted to single branches. In severe cases, plants die. A dark brown lesion, about 0.5 to 1 inch (1–2.5 cm) long, is visible on the tap root or a main lateral root. Often the lesion completely girdles the root. The lesion usually occurs on the roots within the top 12 inches of soil. Internally, a brown discoloration of the vascular system extends 1 to 4 inches from the lesion.

COMMENTS ON THE DISEASE

The fungus probably survives for long periods in the soil as spores. In California, it occurs most commonly north of Merced County. Other host crops are peppers and potatoes.

MANAGEMENT

Limit spread of infested soil by cleaning equipment between fields.

FUSARIUM WILT (12/13)

Pathogen: *Fusarium oxysporum* f. sp. *lycopersici*

SYMPTOMS

The Fusarium wilt fungus infects plants through the rootlets, invading the xylem and eventually extending throughout the plant. Individual branches and associated leaves on plants infected with Fusarium become yellow and wilt. Sometimes only one branch or one side of the plant is affected, creating a yellow flag effect. Infected plants usually die. A dark brown vascular discoloration extends far up the stem. Symptoms often first appear during fruit sizing.

COMMENTS ON THE DISEASE

Symptoms of Fusarium and Verticillium wilts are similar and may require culturing the fungus in a laboratory for positive identification. Fusarium wilt can greatly reduce yields in fields with a high incidence of *Fusarium*. The fungus overwinters and survives for many years in the soil as spores and on the outer surface of other plants, such as weeds and other crops, without causing them harm. Long distance spread is by seed, transplants, and soil on farm machinery. The disease is favored by warm weather.

The fungus only infects tomato but exists as three races. Race 1 is widespread; Race 2 is common in the Sacramento Valley and in the northern San Joaquin Valley; and Race 3 is in the Sacramento Valley and spreading into the San Joaquin Valley.

MANAGEMENT

Use resistant tomato varieties. Resistant varieties are common for Race 1, and many are also resistant to Race 2. A few varieties are resistant to all three races. Limit the spread of infested soil by cleaning farm equipment. Avoid root knot nematode infestations because nematode feeding can overcome the plant resistance to Fusarium wilt. Rotation out of tomatoes for several years reduces inoculum level, although Fusarium is long-lived.

GRAY MOLD (12/13)

Pathogen: *Botrytis cinerea*

SYMPTOMS

Gray mold appears on young plants as gray-brown velvety mold covering stems or leaves. Infections that girdle the stem cause wilting above the infected area. In the field gray spores cover dying flowers and the calyx of fruit. Under a hand lens, the spore-bearing structures resemble bunches of grapes. Infections spread from flowers or fruit back toward the stem, which turns white and develops a canker that may girdle it.

Green fruit decays and turns light brown or gray, starting at the point where it touches other infected plant parts. Small green fruit infected directly by airborne spores instead of by contact with other infections usually does not decay, but develops white, circular rings called "'ghost spots.'" Infected fruit held in storage at high humidity often decays and shows the typical gray coating of spores; it may also have a white mycelium on the surface.

COMMENTS ON THE DISEASE

Gray mold is one of the main causes of postharvest rot of fresh market tomatoes, and it occasionally affects processing tomatoes when there is a rain, heavy dew, or fog before harvest. Careful management of irrigation water keeps the disease to a minimum.

Gray mold can be a problem in greenhouse-grown tomatoes. It can develop where supporting wires and strings rub against stems, causing a wound.

The pathogen also colonizes wounded stems on tomato transplants. When these plants are planted in the field, lesions can girdle the stem, resulting in stand losses.

Botrytis spores originate in the residue of tomatoes, peppers, and weeds and are spread by wind. Spores landing on tomato plants germinate and produce an infection when there is free water on the plant surface from rain, dew, fog, or irrigation. Infection is fastest when the temperature is about 65° to 75° F. Dying flowers are the most favorable sites for infection. Infection may also result from direct contact with moist, infested soil or plant debris.

MANAGEMENT

Cultural Control

Inspect transplants before planting them into the field. Remove and destroy plants found with severe *Botrytis* symptoms such as obvious active lesions or dead leaves or petioles. Also, avoid unnecessary late irrigations and keep the tops of beds dry when fruit is present to help reduce the chance of infection.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop.

Treatment Decisions

Fungicides may be required in fresh market and greenhouse-grown tomatoes if gray mold infections are occurring. Fungicides will not suppress an established infection and are applied to protect against infection.

Fungicides cannot prevent disease development in fruit touching infested soil or plant debris, so treatments are not recommended for processing tomatoes. Infection of bush tomatoes is more likely when vines grow into furrows, allowing fruit to contact irrigation water.

LATE BLIGHT (12/13)

Pathogen: *Phytophthora infestans*

SYMPTOMS

Leaf symptoms of late blight first appear as small, water-soaked areas that rapidly enlarge to form purple-brown, oily-appearing blotches. On the lower side of leaves, rings of grayish white mycelium and spore-forming structures may appear around the blotches. Entire leaves die and infections quickly spread to petioles and young stems. Infected fruit turn brown but remain firm unless infected by secondary decay organisms; symptoms usually begin on the shoulders of the fruit because spores land on fruit from above.

COMMENTS ON THE DISEASE

Late blight is found when humid conditions coincide with mild temperatures for prolonged periods. When humidity is above 90% and the average temperature is in the range of 60° to 78°F, infection occurs in about 10 hours. If conditions are ideal for disease development, disease development is rapid and losses can be severe. The fungus overwinters in potatoes, tomatoes, hairy nightshade, and possibly in the soil. Spores of the fungus are easily spread by wind to other plants.

MANAGEMENT

- Tomato varieties resistant to certain races of the late blight fungus are grown where the disease occurs regularly.
- Remove any nearby volunteer tomato and potato plants and nightshades.
- Check transplants to ensure they are free of late blight before planting.
- Avoid sprinkler irrigation, if possible, because it favors the development of late blight.
- Fungicides are generally needed only if the disease appears during a time of year when rain is likely or overhead irrigation is practiced. Mefenoxam-resistant strains of the pathogen are widespread in California and this fungicide is no longer effective.
- Disc tomato fields in fall to eliminate a winter reservoir for the fungus.

Monitoring and Treatment Decisions

Apply a protectant fungicide before disease development begins; once an outbreak occurs in a field, it is important to apply additional applications at regular intervals. Coverage must be thorough for applications to be effective.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

When choosing a pesticide, consider its usefulness in an IPM program by reviewing thepesticide's properties, efficacy, application timing, and information relating to resistance management,honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

A. FAMOXADONE + CYMOXANIL
(Tanos) 8 oz 12 3
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11) + cyanoacetamide-oximes (27)

B. DIMETHOMORPH
(Zampro) Label rates See label See label
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Cinnamic acid (40)

C. AZOXYSTROBIN
(Quadris F) 6 fl oz 4 0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)
COMMENTS: Apply at 5- to 7-day intervals. Make no more than 2 sequential applications before alternating with fungicides that have a different mode of action. Do not alternate or tank mix with fungicides to which resistance has developed in the pathogen population.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
D. AZOXYSTROBIN + DIFENOCONAZOLE			
(Quadris Top)	8 fl oz	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11) + Dimethylation inhibitor (3)			
E. CHLOROTHALONIL			
(Bravo Weather Stik)	1.5–2 pt	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)			
F. MANCOZEB			
(Dithane M-45)	1.5–2 lb	24	5
(Dithane F-45 Rainshield)	1.2–1.6 qt	24	5
(Penncozeb 75DF)	1.5–2 lb	24	5
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)			
G. PYRACLOSTROBIN			
(Cabrio EG)	8–16 oz	12	0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

MOSAIC DISEASES CAUSED BY POTYVIRUSES (12/13)

Pathogens: *Tobacco etch virus* and *Potato Y virus* in the potyvirus group

SYMPTOMS

Symptoms on plants affected by mosaic diseases can vary. In general, plants develop an overall lighter coloring and a bushy appearance. Close up symptoms include a mosaic (alternating light and dark green areas) on some leaves, especially the younger ones. Leaves may also be curled. Fruit may be distorted and develop mosaic symptoms. Internally, brown areas and necrotic areas develop and the fruit do not ripen normally.

COMMENTS ON THE DISEASES

The tomato potyviruses are transmitted plant-to-plant by many species of aphids. Aphids only retain the ability to transmit these viruses for very short periods of time (minutes to a few hours). Thus, spread is often very rapid and localized. In general, spread of tomato potyvirusesin the field occurs when aphid activity in fields is high. The type of aphid activity that promotes virus spread occurs when aphids actively move through the crop, not when they colonize plants.

The tomato potyviruses have wide host ranges, including other crops and many weed species, particularly within the plant family Solanaceae.

Various strains of the tomato potyviruses exist, some of which differ in their specific pathogenicities. It is common to find plants simultaneously infected by more than oneof the tomato potyviruses, and to also be infected by cucumber mosaic virus.

MANAGEMENT

Because outbreaks of virus diseases are unpredictable from year to year and for various geographic locations, the control of these diseases is difficult and not usually practiced.

The use of silver reflective mulches may delay the infection by aphid-borne viruses and reduces the incidence and severity of these diseases by repelling aphids that transmit them. Place reflective polyethylene mulches on planting beds before seeding or transplanting to reduce aphid landing and virus transmission. The mulches lose their effectiveness when more than 60% of the surface is covered by tomato plant foliage.

Insecticides do not effectively control these viruses because they do not kill the aphids before they can transmit the viruses.

MOSAIC VIRUS DISEASES CAUSED BY CUCUMOVIRUSES (12/13)

Pathogen: *Cucumber mosaic virus* in thecucumovirus group

SYMPTOMS

Symptoms on plants infected with cucumoviruses can vary. Generally, plants appear lighter in color and are bushy and stunted. Close up symptoms include a mosaic (alternating light and dark green areas) on at least some leaves, especially on the younger leaves. Leaves may exhibit a shoestring-like appearance. Fruit production is greatly reduced. These symptoms can be confused with those caused by tobacco mosaic virus.

COMMENTS ON THE DISEASES

Cucumber mosaic virus is spread from plant-to-plant by many species of aphids. Aphids only retain the ability to transmit these viruses for very short periods of time (minutes to a few hours). Thus, spread is often very rapid and local. In general, field spread of *Cucumber mosaic virus* occurs when aphid activity in fields is high. The type of aphid activity that promotes virus spread occurs when aphids actively move through the crop, not when they colonize plants.

There are many strains of cucumber mosaic and it has a very wide host range among dicot crop and weed species. Thus eliminating alternate sources of inoculum is not a feasible management strategy.

MANAGEMENT

Because outbreaks of virus diseasesare unpredictable from year to year and for various geographic locations, the control of these diseases is difficult and not usually practiced.

The use of silver reflective mulches may delay the infection by aphid-borne viruses and reduces the incidence and severity of these diseases by repelling aphids that transmit them. Place reflective polyethylene mulches on planting beds before seeding or transplanting to reduce aphid landing and virus transmission. The mulches lose their effectiveness when more than 60% of the surface is covered by tomato plant foliage.

No good sources of cucumber mosaic resistance in tomatoes are currently available. Efforts are underway to develop resistant cultivars, both through traditional plant breeding and biotechnological approaches.

No pesticide strategies are effective. Insecticides directed at controlling the aphid vectors are ineffective because they cannot kill the aphids before transmission occurs.

PHYTOPHTHORA ROOT ROT (12/13)

Pathogens: *Phytophthora parasitica* and *P. capsici*

SYMPTOMS

The most distinctive symptoms of Phytophthora root rot are the brown lesions on roots of all sizes. The xylem of the roots above the lesions often turns yellowish or brown. In severe cases, nearly all roots may be girdled or rotted off. Aboveground, infected plants are slow growing and may wilt or die in hot weather. When fruit in contact with the ground are infected, the disease is called buckeye rot. Symptoms include tan or brown spots with concentric rings. *Phytophthora capsici* also causes greasy, purple-brown stem lesions.

COMMENTS ON THE DISEASE

Phytophthora parasitica and *P. capsici* occur in most soils. Infection of plants occurs at any stage of growth when there is free water in the soil. Damage is greatest in poorly drained, compacted, or overirrigated soils.

MANAGEMENT

Good water management is key to managing this disease and avoiding the need for fungicide treatments.

Cultural Control

Provide good drainage and prevent flooding. Avoid wide fluctuations in soil moisture, which predisposes plants to infection. Keep tops of bed dry to avoid buckeye rot of the fruit. Planting cereals as a rotation crop may reduce the level of infestation in the soil. Resistant varieties are not yet commercially available.

Organically Acceptable Methods

Cultural control is acceptable in an organically certified crop.

Chemical Control

Fungicides are needed only in poorly drained soils or where root rot is historically a problem.

Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management, honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.			
A. MEFENOXAM (Ridomil Gold SL)	1 pt	48	7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Phenylamide (4)			
COMMENTS: Follow application with an irrigation (see label).			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

POWDERY MILDEW on FIELD-GROWN TOMATOES (12/13)

Pathogens: *Leveillula taurica (Oidiopsis taurica)*

SYMPTOMS

Leaves on infected tomato plants develop irregular, bright yellow blotches; severely affected leaves die but seldom drop. Spots of dead tissue, sometimes surrounded by a yellow halo, eventually appear in the blotches. Abundant white sporulation may be observed on upper or lower leaf surfaces. There are no lesions on stems or fruit. As the disease progresses leaves die, resulting in sunburn damage on fruit, reduced soluble solids, and weakened plants.

COMMENTS ON THE DISEASE

Powdery mildew occurs in most tomato-growing areas of California. The fungus infects weeds and crops in the solanaceous family; spores are carried by wind to tomato plants. The disease usually is most severe late in the season. High relative humidity favors disease development. Mild temperatures favor infection while higher temperatures hasten the death of infected leaves. Plants stressed by other problems appear to be more susceptible to powdery mildew.

MANAGEMENT

When conditions are conducive to disease development and sporulation is abundant, fungicide applications may be necessary to control powdery mildew.

Organically Acceptable Methods

Bacillus pumilus and some sulfur sprays may be acceptable for use on organically certified produce. Check with your certifier before use.

Monitoring and Treatment Decisions

A weather-based, forecasting model is available online. The model attempts to predict the occurrence of powdery mildew based on temperature, relative humidity, and leaf wetness. However, since 2007 the disease has been more severe and faster developing such that disease severity and fungicide timings have not been well predicted by the model in recent years.

Fungicides may not be needed on early-season crops harvested in July or August. In the Central Valley, disease outbreaks generally start in July or August and mainly affect plants that are at full-bloom or a later stage. Multiple, early applications of sulfur dust are the most effective option; once the disease becomes severe, control is difficult. Apply fungicides if needed preventatively or during the early infection period. When disease pressure is high, repeat fungicide applications at 7-day intervals to control the disease. Stop treatments within two weeks of harvest.

There are no immune tomato varieties in California, though varieties vary in susceptibility.

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
	When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management, honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.			
A.	SULFUR#	Label rates	24	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M2)			
	COMMENTS: Do not use if an oil was applied recently or will be in the near future.			
B.	AZOXYSTROBIN + DIFENOCONAZOLE (Quadris Top)	8 fl oz	12	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11) + Dimethylation inhibitor (3)			
C.	FLUXAPYROXAD + PYRACLOSTROBIN (Priaxor Xemium)	6–8 fl oz	12	7
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate dehydrogenase inhibitor (7) + Quinone outside inhibitor (11)			

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
D.	AZOXYSTROBIN			
	(Quadris F)	5–6 fl oz	4	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)			
	COMMENTS: Apply on a 7- to 14-day interval; make no more than three sequential applications before alternating with a fungicide that has a different mode of action. Do not alternate or tank mix with fungicides to which resistance has developed in the pathogen population.			
E.	PYRACLOSTROBIN			
	(Cabrio EG)	8–16 oz	12	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)			
F.	WETTABLE SULFUR	Label rates	24	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M2)			
	COMMENTS: Do not use if oil was applied recently or will be in the near future.			
G.	PENTHIOPYRAD			
	(Fontelis)	See label	12	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate dehydrogenase inhibitor (7)			
H.	MYCLOBUTANIL			
	(Rally 40WSP)	2.5–4 oz	24	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)			
I.	BACILLUS PUMILUS STRAIN QST2808#			
	(Sonata)	2–4 qt	4	0
	MODE OF ACTION: A biological antagonist.			
	COMMENTS: Begin applications before disease onset or when disease pressure is low. Repeat at 7- to 10-day intervals.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitableto alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

POWDERY MILDEW ON GREENHOUSE & COASTAL TOMATOES (12/13)

Pathogens: *Oidium neolycopersici*

SYMPTOMS

Symptoms of powdery mildew are limited to leaves. Symptoms initially appear as light green to yellow blotches or spots that range from 0.125 to 0.5 inch (3–12 mm) in diameter on the upper surface of the leaf. A white, powdery growth ofthe fungal mycelia and spores is obvious on the top of leaves. As spots coalesce, the leaf tissue dies. The entire leaf eventually turns brown and shrivels but remains attached to the stem.

COMMENTS ON THE DISEASE

In California, powdery mildew caused by *O. neolycopersici* is limited to greenhouses and fields close to the coast. Conidia are easily windborne and are carried long distances. The conidia land on leaves where they germinate and enter the leaf stomata. The fungus grows at moderate to cool temperatures. Little moisture is required for the fungus to establish itself on a plant. There is experimental evidence that the pathogen has a wide host range and probably survives on other hosts or volunteer tomato plants from season to season.

MANAGEMENT

This powdery mildew is generally not severe in coastal fields and control measures are usually not warranted. Greenhouse-grown tomatoes, however, can suffer to the point of severe economical damage. Registered fungicides, such as sulfur, may be required to control the disease in the greenhouse. Begin applications when the disease first appears.

Organically Acceptable Methods

Sulfur sprays are acceptable for use on organically certified produce.

	Common name (example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)
	When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management, honey bees (PDF), and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.			
A.	SULFUR#	Label rates	24	0
	MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M2)			
	COMMENTS: Do not use if an oil was applied recently or will be in the near future.			

** See label for dilution rate.

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

SOUTHERN BLIGHT (12/13)

Pathogen: *Sclerotium rolfsii*

SYMPTOMS

Tomato plants with southern blight have lesions on the stem at or near the soil line. These lesions develop rapidly, girdling the stem and resulting in a sudden and permanent wilting of the plant. White mats of mycelia are produced on the stem and in the adjacent soil. In a few days, tan to brown spherical sclerotia about 0.06 inch (0.5 mm) in diameter appear on the mycelial mat. The abundant sclerotia are a good diagnostic feature.

COMMENTS ON THE DISEASE

Southern blight is not a common disease of tomatoes. High temperatures (above 85°F, 29°C) favor the disease, which occasionally causes damage to tomato crops grown in the Central Valley.

The fungus attacks a wide range of plants and survives for long periods in soil as sclerotia. Disease incidence and severity are dependent on the number of sclerotia in the soil.

MANAGEMENT

- Rotate to nonhost crops, such as corn, sorghum, rice, or small grains, for at least 2 years to reduce inoculum.
- Deep plowing to bury plant refuse may help to destroy sclerotia.
- Keeping the tops of beds dry in tomato fields helps reduce the disease in furrow- and buried-drip-irrigated fields.

TOBACCO MOSAIC (12/13)

Pathogens: Various Tobamoviruses including *Tobacco mosaic virus* and *Tomato mosaic virus*

SYMPTOMS

Symptoms on tomato plants infected with *Tobacco mosaic virus* vary with the cultivar and the specific virus or strain. A mild mosaic develops on leaves with some leaf malformation, including a fernlike appearance. During cool weather shoestringlike symptoms appear on leaves, which is also characteristic of *Cucumber mosaic virus* in tomato. Necrotic patterns may develop on fruit.

COMMENTS ON THE DISEASES

These viruses are commonly encountered in transplants or fresh market tomatoes where the plants are trained or handled by workers because the viruses are easily mechanically transmitted. There are many sources of these viruses, including tobacco products, tomato seed, infected plant debris, and equipment; the tobamoviruses are not transmitted by insect, nematode or fungal vectors. The tobamoviruses are very stable viruses and can survive in plant debris for a number of years. These viruses are seldom seen in direct-seed fields.

MANAGEMENT

Use seed that has been treated to eliminate seedborne inoculum. Extreme sanitation is needed. The disease is difficult to control if the plants have to be handled. Some cultivars have genetic resistance to specific tomato-infecting tobamoviruses.

TOBACCO STREAK (12/13)

Pathogen: *Tobacco streak virus* in the ilarvirus group

SYMPTOMS

Downward curling of leaf blades on tomato plants with tobacco streak is common. Leaf veins become necrotic and can lead to necrotic blotches, especially on young leaves. Fruit may develop necrotic ringspots. Necrotic streaks on young stems extend to flowers and leads to flower drop.

COMMENTS ON THE DISEASE

Tobacco streak is a widespread disease of tomato, but it generally does not cause major losses. Spread of the virus is associated with pollen and/or thrips (including western flower thrips, *Frankliniella occidentalis*, and the onion thrips, *Thrips tabaci*). Seed transmission is reported to occur in some beans, chickpeas, and weeds. The host range for this virus is wide and includes common weeds such as mustards, radishes and thistles.

MANAGEMENT

There is no genetic resistance to tobacco streak in tomatoes and no effective management strategies are available.

TOMATO BIG BUD (12/13)

Pathogen: *Beet leafhopper transmitted viresence agent* (BLTVA)

SYMPTOMS

The most striking symptom of tomato big bud is the large, swollen green buds that fail to develop normally and do not set fruit. Apical stemsare thick and assume an upright growth habit. Infected plants appear bushy because of shortened internodes and small leaves. Leaves are distorted and yellow-green. Aerial roots may develop on stems.

COMMENTS ON THE DISEASE

Tomato big bud is an uncommon disease in California except in western Fresno County where it occurs regularly. Beet leafhopper transmitted viresence agent, a phytoplasma organism, is transmitted by the beet leafhopper, *Circulifer tenellus*. Beet leafhopper transmitted viresence agent has a wide host range, including many vegetables and weeds. The disease is dependent on populations of the leafhopper and reservoirs of the mycoplasmalike organism.

MANAGEMENT

Management of tomato big bud is not practiced in California.

TOMATO BUSHY STUNT (12/13)

Pathogen: *Tomato bushy stunt virus* of the tombusvirus group

SYMPTOMS

Leaves on plants infected with *Tomato bushy stunt virus* are small in size, cupped, and curled downward. The youngest leaves are twisted and exhibit tip necrosis. A proliferation of lateral shoots leads to an overall bushy appearance. Lower leaves are chlorotic with a purple tinge. Plants may be stunted. Fruit yield is greatly reduced.

COMMENTS ON THE DISEASE

There is no known vector of *Tomato bushy stunt virus*, although virus incidence is often associated with the soil and may be spread with irrigation water. *Tomato bushy stunt virus* apparently gains entry to host plants through wounds in damaged root cells. In California, tomato bushy stunt decline is limited to the Imperial Valley.

MANAGEMENT

There is no genetic resistance in tomatoes to tomato bushy stunt, and no control measures have been developed. Avoid fields that have a history of tomato bushy stunt. Long crop rotations (4 years) may be helpful. Attempts to develop genetically engineered resistance for tomato bushy stunt in tomatoes are underway.

TOMATO INFECTIOUS CHLOROSIS (12/13)

Pathogen: *Tomato infectious chlorosis virus*

SYMPTOMS

The leaves of plants infected with *Tomato infectious chlorosis virus* become yellow or red between the veins, stunted, and rolled. Symptoms generally occur on older leaves, while new growth continues to appear normal. As the disease progresses, interveinalnecrosis can occur and the leaves become characteristically brittle, thick, and crisp.

COMMENTS ON THE DISEASE

Outbreaks of virus diseases are unpredictable from year to year and for various geographic locations. This virus is transmitted by the greenhouse whitefly, *Trialeurodes vaporariorum*. Although the disease has the potential to cause severe losses to both fresh market and greenhouse-grown tomatoes, it generally causes minor losses. In addition to tomato, this virus infects a wide array of weeds, crops, and ornamentals, including bristly oxtongue (*Picris echloides*), groundsel (*Senecio vulgaris*), sowthistle (*Sonchus oleraceus*), shepherd's-purse (*Capsella bursa-pastoris*), artichoke (*Cynera scolymus*), lettuce (*Lactuca sativa*), potato (*Solanum tuberosum*), zinnia (*Zinnia elegans*), and petunia (*Petunia hybrida*).

MANAGEMENT

- Minimize exposure to this virus by avoiding overlap with other susceptible crops.
- Avoid using infected transplants.
- Roguing of infected plants and general whitefly control may help reduce virus spread.

TOMATO PITH NECROSIS (12/13)

Pathogen: *Pseudomonas corrugata*

SYMPTOMS

Tomato pith necrosis affects mature tomato plants. Symptoms include a brown discoloration and necrosis of the pith, which eventually leads to hollow chambers in the stem. The pith browning usually extends far up the plant. Profuse adventitious roots are associated with the stem where the pith is affected. Gray or dark brown lesions may appear on the surface of the stem. Affected plants may turn chlorotic and wilt.

COMMENTS ON THE DISEASE

Pith necrosis occurs when the first fruit set is close to mature green. High humidity favors its development. The bacterium may be seedborne. In California it is seen primarily in greenhouses, but can occur in fresh market tomato fieldsin the southern part of the state, and occasionally, but rarely, in Central Valley tomatoes.

MANAGEMENT

Management for tomato pith necrosis is not practiced in California.

TOMATO SPOTTED WILT (12/13)

Pathogen: *Tomato spotted wilt virus* in the tospovirus group

SYMPTOMS

Plants infected with *Tomato spotted wilt virus* exhibit bronzing of the upper sides of young leaves, which later develop distinct, necrotic spots. Leaves may be cupped downward. Some tip dieback may occur. On ripe fruit chlorotic spots and blotches appear, often with concentric rings. Green fruit show slightly raised areas with faint, concentric zones.

COMMENTS ON THE DISEASE

Tomato spotted wilt virus is transmitted by various species of thrips, including the western flower thrips, *Frankliniella occidentalis*, the onion thrips, *Thrips tabaci*, and the chili thrips, *Scirtothrips dorsalis*. *Tomato spotted wilt virus* also infects the thrips vector. Nymphs that acquire the virus by feeding on infected plants will retain the ability to transmit it for the remainder of their lives. *Tomato spotted wilt virus* cannot be passed from infected females through the eggs.

The virus has an extremely wide host range, including many weeds and ornamentals as well as crop hosts. It is one of the few plant viruses with a host range that includes dicots and monocots (e.g., tomatoes and onions). Recent outbreaks have occurred in the San Joaquin Valley where they are believed to be associated with nearby infested crops or weeds.

MANAGEMENT

Management of tomato spotted wilt is generally not practiced in California, but in areas where it is known to occur, plant resistant varieties and control western flower thrips and onion thrips when the virus is detected early.

Before the growing season:

- Plant resistant tomato varieties with the Sw-5 gene. Resistant varieties generally do not require insecticide applications for thrips to control tomato spotted wilt.
- Use virus- and thrips-free transplants from greenhouses that manage thrips and inspect transplants.
- Manage thrips on transplants before planting.

During the growing season:

- Avoid planting near crops infected with *Tomato spotted wilt virus*.
- Monitor for thrips and tomato spotted wilt symptoms.
- If thrips are present and symptoms are observed, manage thrips to minimize the spread of the virus within the field.
- Consider removing infected plants at the seedling stage.
- Control weeds in and around fields.

After the growing season:

- Promptly remove and destroy old tomato plants and other host crops after harvest.
- Control weeds and volunteer plants in fallow fields, non-cropped, or idle land near next year's tomato field.

TOMATO YELLOW LEAF CURL (12/13)

Pathogen: *Tomato yellow leaf curl virus* (TYLCV)

SYMPTOMS

Tomato yellow leaf curl is a disease of tomato caused by *Tomato yellow leaf curl virus*. In March 2007, it was identified for the first time in California and currently has a limited distribution. An educational brochure (PDF) was created at that time and is available to print.

Infected tomato plants initially show stunted and erect or upright plant growth; plants infected at an early stage of growth will show severe stunting. However, the most diagnostic symptoms are those in leaves.

Leaves of infected plants are small and curl upward; and show strong crumpling and interveinal and marginal yellowing. The internodes of infected plants become shortened and, together with the stunted growth, plants often take on a bushy appearance, which is sometimesreferred to as 'bonsai' or broccoli'-like growth. Flowers formed on infected plants commonly do not develop and fall off (abscise). Fruit production is dramatically reduced, particularly when plants are infected at an early age, and it is not uncommon for losses of 100% to be experienced in fields with heavily infected plants.

COMMENTS ON THE DISEASE

Tomato yellow leaf curl virus is undoubtedly one of the most damaging pathogens of tomato, and it limits production of tomato in many tropical and subtropical areas of the world. It is also a problem in many countries that have a Mediterranean climate such as California. Thus, the spread of the virus throughout California must be considered as a serious potential threat to the tomato industry.

There are a number of factors why it has not yet spread to all the major tomato-producing areas of California, including the Sacramento and San Joaquin valleys. First, its vector, *Bemisia* whitefly species are not typically found in these tomato-producing areas because it is intolerant of winter temperatures there. Second, the Central Valley's winter season provides a 'natural' tomato-free period, which usually goes from late November through early February. Although the virus can infect other plants, tomato is the host in which it builds-up most quickly. Thus, by having an annual 'tomato-free period', it is likely that the amount of viral inoculum (as well as whitefly populations) will be significantly reduced by the time the tomato planting season startagain in late winter-early spring. This would mean that, even if the virus is able to overwinter, it may take a long time to reach levels that cause economic damage.

Tomato yellow leaf curl virus is a geminivirus (family Geminiviridae). Although it can infect a relatively wide range of plant species, tomato is the host to which the virus is best adapted and that facilitates the build-up of the virus to high incidences in the field. Other hosts includes solanaceous crops, which may develop symptomless infections, and weeds (e.g., nightshade and jimsonweed).

In addition, the virus causes leaf curl in certain varieties of common bean (*Phaseolus vulgaris*) and the ornamental plant lisianthus (*Eustoma grandiflorum*). A range of weeds from other families can be infected by this virus, but most of these do not develop obvious disease symptoms. It is not known how well whiteflies acquire the virus from symptomless hosts. However, it has been hypothesized that these hosts serve as a 'bridge' for the virus in the absence of tomato crops, and that perennial weeds help allow the virus to become permanently established.

The primary way the virus is spread short distances is by *Bemisia* whitefly species. Over long distance, the virus is primarily spread through the movementof infected plants, especially tomato transplants. Because it can take up to 3 weeks for disease symptoms to develop, infected symptomless plants could be unknowingly transported. The virus also can be moved long distance by virus-carrying whiteflies that are transported on tomatoes or other plants (e.g., ornamentals) or via high winds, hurricanes, or tropical storms.

COMMENTS ON CONTROL

Rapid and precise tests for *Tomato yellow leaf curl virus* are available at UC Davis and CDFA. These tests can be carried out in less than 24 hours. Anyone finding tomatoes with TYLC-like symptoms can contact their county farm advisor, Robert L. Gilbertson at UC Davis (telephone: (530) 752-3163 and e-mail: (rlgilbertson@ucdavis.edu) or Tongyan Tian at CDFA (telephone: (916) 262-1127 and e-mail: TTian@cdfa.ca.gov).

Strategies to effectively manage the disease include:

Before planting

- Select TYLCV-resistant varieties.
- Use virus- and whitefly-free transplants.
- DO NOT import tomato (or any potential whitefly host) transplants from areas known to have the virus (Florida, Georgia and Texas in the U.S.; and Mexico).

During the growing season

- Plant immediately after any tomato-free period or true winter season.
- Avoid planting new fields near older fields (especially those with TYLCV-infected plants).
- Manage WHITEFLIES.
- Cover plants with floating row covers of fine mesh (Agryl or Agribon) to protect from whitefly infestations.
- Rogue diseased plants when incidence of virus infection is low.
- Practice good weed management in and around fields to the extent feasible.

After the growing season

- Remove and destroy old crop residue and volunteers on a regional basis.
- A voluntary or enforced regional host-free period in areas lacking a true winter season (i.e., temperatures low enough to prevent crop cultivation and whitefly survival) might be a useful management tool. The crops to be included in a region will depend on the agroecosystem.

VERTICILLIUM WILT (12/13)

Pathogen: *Verticillium dahliae*

SYMPTOMS

Older leaves on tomato plants infected with *Verticillium* appear as yellow, V-shaped areas that narrow from the margin. The leaf progressively turns from yellow to brown and eventually dies. Older and lower leaves are the most affected. Sun-related fruit damage is increased because of the loss of foliage. A light tan discoloration develops in the vascular tissue, especially near the base of the plant. The discoloration extends a short distance up the plant and may occur in patches. Symptoms are most noticeable during later stages of plant development when fruit begin to size.

COMMENTS ON THE DISEASE

The fungus survives as microsclerotia in the soil. Once established in a field, it persists indefinitely and can cause disease whenever a susceptible host is planted. A large number of crops and weeds serve as hosts. The disease is favored by cool soil and air temperatures.

Verticillium wilt is difficult to distinguish from Fusarium wilt and positive identification may require cultivating the fungus in a laboratory. Verticillium wilt seldom kills tomato plants but reduces their vigor and yield.

MANAGEMENT

- Use resistant cultivars effective against Race 1. No source of resistance to Race 2 is commercially available.
- Sanitation, especially washing equipment to prevent movement of infested soil, may help to slow spread of the Race 2 strain of the pathogen.
- Rotation to nonsusceptible crops, such as small grains and corn, helps reduce inoculum.

WATER MOLD (FRUIT ROT) (12/13)

Pathogens: *Pythium ultimum* and other species

SYMPTOMS

Water-soaked lesions develop on ripe fruit in contact with wet soil. Within several days, the entire infected fruit turns into a water bag.

MANAGEMENT

Avoid late-season irrigation, especially when threat of rainfall increases. Avoid wetting the top of beds when fruit is ripening. Shorter furrow irrigation runs and higher beds may lessen risk.

WHITE MOLD (12/13)

Pathogen: *Sclerotinia sclerotiorum*

SYMPTOMS

White mold generallyappears on tomato plants at flowering. Symptoms include water-soaked areas on flowers and at stem joints where senescent flower petals have fallen. The infection quickly kills stems, which eventually dry and take on a bleached appearance. Water-soaked stem lesions may also appear at the soil line if senescent plant debris is present around the plant. Affected areas generally show white, cottony mycelium that soon produces large, irregularly shaped, black sclerotia. Infected fruits turn gray and rot. Sclerotia on infected fruits are usually produced at the point of attachment with the plant.

COMMENTS ON THE DISEASE

Sclerotia survive in the soil. When they are within the top 0.8 to 1.2 inches (2–3 cm) of soil they can germinate to form a saucer-shaped fruiting body called an apothecium. Each apothecium produces millions of ascospores that are disseminated by wind. A single sclerotium may produce up to five to six apothecia, depending on environmental conditions. High soil moisture and temperatures of 49° to 59°F (9° to 15°C) favor apothecial production. Because ascospores germinate on and colonize dead or senescent tissue, senescent flowers are frequently the source of new infections. Occasionally infections may originate before flowering from mycelium in the soil that is in direct contact with injured stem tissue.

Both infection and subsequent spread of the disease are determined by temperature and moisture conditions. White mold is favored by cool (59° to 70°F, 15° to 21°C), moist (16 to 72 hours of continuous wetness) conditions. Disease is most severe in low-lying, waterlogged parts of the field.

MANAGEMENT

White mold is generally a minor disease of tomato and specific controlmeasures are usually not warranted. White mold can be difficult to control because infection is caused by both airborne ascospores and soilborne sclerotia. Because of the very wide host range of the pathogen, routine crop rotations are not effective. Most infections are initiated by airborne ascospores, consequently simple sanitation methods around a tomato field do not provide effective white mold control. In years with severe white mold infections, sclerotia in the soil have the potential to create a long-term problem.

Cultural Control

- Attempts to breed for crop resistance against white mold have largely been unsuccessful and currently no resistant tomato cultivars are available.
- The usefulness of crop rotations and deep-plowing to reduce soilborne inoculum are also limited.
- Decreased planting densities may open plant canopies to create a less favorable environment for white mold development.
- Subsurface drip irrigation prevents alternating soil wetting and drying, which favors germination of sclerotia and keeps the soil surface dry, creating less favorable conditions for infection. Subsurface drip irrigations may, therefore, provide a significant, long term control of white mold.

Organically Acceptable Methods

Use cultural control methods.

Nematodes

(Section reviewed 12/13)

ROOT KNOT NEMATODE (12/13)

Scientific Name: *Meloidogyne* spp.

DESCRIPTION OF THE PEST

Mature female root knot nematodes are pear-shaped and about 0.01 inch long. Root knot nematodes spend most of their life in galls. Mature females resemble tiny, white pearls; they sometimes can be seen with the use of a hand lens when root galls are cut open.

DAMAGE

Root knot nematodes cause characteristic galls on roots; galls may be up to 1 inch in diameter, but are usually smaller. These galls interfere with the flow of water and nutrients to the plant; infected plants appear less vigorous than healthy plants, may be yellowed,are prone to wilt in hot weather, and respond poorly to fertilizer. Damage areas usually appear as irregular patches and are frequently associated with lighter-textured soils.

MANAGEMENT

Assess the population level and damage potentialbased on soil sampling or the history of injury in previous crops. Because root knot nematodes feed and multiply on many weed species, weed control is an important aspect of their management.

Cultural Control

Several varieties are resistant to nematodes and should be used where nematodes are present. Rotation with resistant varieties and nonhost crops is as effective as fumigation. Resistant tomato varieties are not effective against the species *Meloidogyne hapla*, but are effective against *M. incognita*, *M. javanica*, and *M. arenaria*. Cotton is susceptible only to *M. incognita* and has relatively high tolerance to even that species. Certain varieties of alfalfa and black-eyed peas are resistant to some root-knot species, but *M. hapla* builds to high numbers on alfalfa.

Soil solarization can provide control of many soilborne diseases, nematodes, and weed pests. For further information, contact your local farm advisor or see UC ANR Publication #21377, *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds.*

Organically Acceptable Methods

Cultural control is acceptable for use on an organically certified crop.

Monitoring and Treatment Decisions

Although soil sampling provides more detailed information, checking for root galls is a simple way to confirm that aboveground symptoms are caused by root knot nematode injury. Check the roots of a few plants in midseason or later, even if the crop appears healthy. Check earlier if you see wilting, poor growth, or other symptoms; galls may appear as soon as a month after planting. Carefully brush or wash soil from roots to look for galls. Be sure to check some plants in the sandiest part of the field, where damage is most likely.

Check the roots of rotation crops as well, but remember that galls will not be present on nonhost crops and may not be as obvious on other susceptible crops as on tomatoes. If the field has been fallowed or planted to a nonhost crop, look for root galls on nightshades and groundcherries. Other weeds may also have galls but are less reliable indicators of root knot activity.

If you find galls on any host plant, you can assume that susceptible varieties of tomatoes in the same soil would be infected. However, absence of root galls on other plants does not necessarily mean the soil is free of nematodes that could injure tomatoes.

Soil Sampling

Soil sampling provides the best basis for management decisions, especially in coarse textured soils. You can sample whenever the soil is in good working condition, but the best times are in spring before planting and in fall after harvest.Because of the gradual decline in populations over the winter and the gradual increase during

summer, samples from fall and spring represent the high and low extremes of the population. Sampling at other times yields immediate results that are more difficult to interpret.

Farm advisors can help you find a laboratory equipped for extracting and identifying nematodes from soil samples. The analysis usually takes about 2 weeks; allow enough time before planting to choose varieties and to treat the soil if necessary. Contact the lab, before you start, to ensure that samples can be processed as soon as they are received. Follow these instructions, but also consult the lab for any special instructions.

- Draw a field map showing areas that differ in soil texture, cropping history, or crop injury.
- Use a grid pattern to divide each area into blocks of 10 acres or less; if conditions are uniform throughout the field, apply the grid to the whole field.
- Use an auger or soil tube to collect soil from at least 20 places in each block. Take moist soil from a depth of at least 18 inches; take deeper samples in dry, fallow ground. Avoid places where soil is too wet or compacted; if surface soil is dry, discard it and include only moist soil. Samples should include roots of any crops or weeds that might be present.
- Thoroughly mix the soil from one block in a bucket or large bag, then transfer it to a plastic bag or other moisture-proof container.
- Label the sample with the block number in pencil on the outside of the container; moisture will ruin labels placed inside.
- Keep the samples cool; do not leave them in the sun or freeze them. The best storage temperature is 50° to 60°F. Seal the containers so they will not dry out. A good way to keep samples in good condition is to put them in an ice chest in the field.
- Send or deliver samples to the lab immediately. Ship them in an ice chest or in a box insulated with newspaper.

Interpreting the Results

The number of root knot juveniles in soilsamples can be a reliable guide to potential yield loss in processing tomatoes; below a certain level, the population has no measurable effect, but yield declines as the number of nematodes increases. If lab results are to be useful, however, you must interpret them carefully.

Labs generally report the number of root knot juveniles found in a certain weight of soil, usually 100 grams or 1 kilogram. The most common extraction apparatus, the Baermann funnel, extracts only those juveniles already free in thesoil; an added mist chamber improves accuracy by promoting the hatching of juveniles from any eggs the samples may contain. All reports should specify the extraction method used.

If your lab reports the estimated total number of juveniles in soil samples, you can use these figures directly in making management decisions. If the lab only reports the number extracted from the samples, then you must also know the recovery rate, or efficiency, of the lab procedure. The recovery rate tells you what percentage of the nematodes in samples in actually extracted; for root knot juveniles, it is usually from 10 to 30%. To get the total, divide the number extracted by the recovery rate and multiply by 100. For example, if the lab extracted 30 juveniles per kilogram and the recovery rate is 20%, the total would be (30÷20) x 100, or 150 per kilogram. When comparing results from two sets of samples, make sure the same unit of soil weight was used in both cases; otherwise, adjust the figures accordingly before comparison.

The table below is a guide to yield loss that can be expected from a given root-knot nematode population in the San Joaquin Valley. With an estimate of expected yield loss, you can judge whether management options will increase net return. For example, ifa lab finds 200 juveniles per kilogram in spring samples of sandy loam soil, the expected yield would drop to about 88% of normal. If normal yield were 30 tons per acre, the yield loss would be 12% of 30, or 3.6 tons per acre. When tomatoes are worth $54per ton, the value of the loss is $54 x 3.6, or $194.40 per acre. If the cost of soil treatment is less, it will increase net return. The same logic applies to selection of a resistant variety or alternate crop that may cost more to plant or have lower value.

The table is based on samples taken in sandy loam soil; on finer textured soils, such as silt loams or clay loams, the expected yield reduction for a given population would be less than the value in the table. It would also be somewhat lower in areas with cooler springtime soil temperatures. The expected loss would be higher in hot desert soils and in the presence of Fusarium wilt.

EFFECT OF ROOT KNOT NEMATODES ON PROCESSING TOMATO YIELD IN SAN JOAQUIN VALLEY SANDY LOAM SOILS

Number of Root Knot Juveniles Per Kilogram in Soil Samples		Percent of Normal Yield
FALL SAMPLES	SPRING SAMPLES	%
0-160	0-25	100
310	50	98
620	100	95
940	150	91
1250	200	88
1560	250	85
1870	300	82
2190	350	79
2500	400	77
2810	450	74
3120	500	72
3440	550	69
3750	600	67
4060	650	65
4370	700	63
4690	750	61
5000	800	60
5310	850	58
5620	900	56
5920	950	55
6250	1000	53

There is no formula for predicting yield loss outside the San Joaquin Valley, but analysis of soil samples in other areas can show whether a population is changing from year to year and can identify parts of the field where root knot nematodes are concentrated. Although the numbers may differ, the general relation between population and yield is probably similar in all areas.

Several kinds of nematodes other than root knot nematodes are found in tomato soils and may be listed in lab reports. These include stunt nematodes (*Tylenchorhynchus* spp.), spiral nematodes (*Heliotylenchus* spp.), pin nematodes, (*Paratylenchus* spp.), and stubby root nematodes (*Trichodorus* and *Paratrichodorus* spp.). None of these affects tomato in California; they generally feed on rotation crops or weeds. Certain root lesion nematodes (*Pratylenchus* spp.) injure tomatoes in other states, but the most common species in California tomato soils *P. thornei,* feeds on grasses and small grains.

Common name (example trade name)	Amount to use** (dosage/acre)	R.E.I.‡ (hours)

When choosing a pesticide, consider its usefulness in an IPM program by reviewing the pesticide's properties, efficacy, application timing, and information relating to resistance management and environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

PREPLANT

A. 1,3-DICHLOROPROPENE* + CHLOROPICRIN*
(InLine) — Label rates — See label
COMMENTS: Multi-purpose liquid fumigant for the preplant treatment of soil against plant-parasitic nematodes, symphylans and certain soil-borne pathogens using drip irrigation systems only. Use of a tarp seal is mandatory for all applications of this product. Fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

B. 1,3-DICHLOROPROPENE*
(Telone EC) — Label rates — See label
COMMENTS: Liquid fumigant for the preplant treatment of soil against plant-parasitic nematodes and certain other soil pests in cropland using drip irrigation systems only. Fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

C. METAM SODIUM*
(Vapam HL, Metam CLR 42%) — Label rates — See label
COMMENTS: For use in sprinkler or furrow-irrigated tomatoes. Apply with enough water to penetrate 18–24 inches and treat at least 50% of planting bed width. Blade injection of metam sodium into preformed beds for weed control gives erratic nematode control; apply with irrigation water for best control of nematodes. Follow recommended waiting period on label before planting to avoid injury to tomato plants. Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when othermanagement strategies have not been successful or are not available.

PREPLANT AND POSTPLANT

A. OXAMYL*
(Vydate) — Label rates — 48
COMMENTS: Oxamyl can be applied through drip irrigation lines. Apply before seeding or transplanting; repeated application is needed for continued protection during the growing season.

** See label for dilution rates.

‡ Restricted entry interval(R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing.

* Permit required from county agricultural commissioner for purchase or use.

Weeds

(Section reviewed 11/11)

INTEGRATED WEED MANAGEMENT (11/11)

Weeds reduce yields by competing for space, light, water, and nutrients, weakening crop stand, and by reducing harvest efficiency. Some weeds can also increase pest problems by serving as hosts for insects, diseases, or nematodes. Weeds are most competitive if they emerge prior to or at planting until about 6 to 8 weeks after crop emergence (fewer weeks when using transplants). After 6 to 8 weeks, tomatoes become more competitive and they are usually less affected by late-germinating weeds. However, even late germinating weeds can produce seed and, in some instances, interfere with harvest.

Effective weed management in tomatoes involves crop rotation practices, cultivation, proper field preparation, sanitation, irrigation management, and proper selection of herbicides. When combined with good cultural practices, available herbicides can control many of the weed species that are found in tomato fields. Herbicide choice depends on the weed species that are present, the cultural practices followed by the grower, and the crops planted following tomato.

In tomato production, many growers establish beds in fall to facilitate early spring planting; some beds may be treated with an herbicide at this time. Herbicides may also be applied several weeks before planting, at the time of planting, after planting but before crop and weed emergence, after crop and weed emergence, or after thinning or transplanting. Herbicides can be classified according to their use as **preemergence** (controls weeds after the seeds germinate but before they emerge from the soil and usually provides residual control) and **postemergence** (controls emerged weeds but gives little or no residual control). Preemergence herbicides are absorbed by roots, emerging shoots (hypocotyl), or both. Postemergence herbicides are absorbed by leaves and stems of weeds. Some herbicides have both preemergence and postemergence activity.

Herbicides work best if soil moisture is adequate for plant growth. However, do not apply these materials when the soil is too wet because soil compaction can occur during application and the herbicide may not be uniformly mixed in the soil where mechanical incorporation is required. Preemergence herbicides will kill germinating seeds but not dry seeds. Postemergence herbicides work best on plants that are not moisture stressed. Nonstressed plants more effectively translocate the herbicide from where it is absorbed (mostly leaves) to the site of action.

MONITORING

Identification and knowledge of target weeds is essential for weed management in tomatoes because it influences management decisions, like herbicide selection. Conduct weed surveys on each field at least twice a year: the first after crop planting but before weeding, and the second just before harvest. Record observations on a monitoring form *(available online).* Note the location of weeds producing seed as carefully as possible. Weed clusters are often stable through time and may require additional spot treatment to achieve effective control. Records from previous crops will indicate which weeds escaped control and will likely infest the tomato crop. Also, examine fence rowsand ditch banks because these are other sources for weed invasion. Give special attention to surveying perennials and marking their locations on a map of the field for follow-up control action.

WEED MANAGEMENT POSTHARVEST AND BEFORE PLANTING

Crop rotation

Crop rotation can effectively reduce difficult weed problems by altering the environmental conditions that favor a particular weed species or by permitting the use of alternative methods to control these weeds. Corn is considered a good rotational crop for tomatoes because some corn herbicides have the ability to control nightshade, yellow nutsedge, and field bindweed, and corn is not a host for dodder. Alfalfa hay is also a good choice for a rotational crop because its frequent cutting cycle reduces many weeds, and herbicides available to use on this crop eliminate most other weeds. Other crops considered as useful rotational crops with tomatoes include wheat, cotton, rice, dry beans, onions, carrots, and safflower. Rotational crops that are not recommended include other solanaceous crops such as potatoes, peppers, and eggplant because they are genetically similar, and all but potatoes have similar cultural practices. Similar herbicides are used in these crops, which often result in common uncontrolled weeds. For the same reasons, monocropping of tomatoes is also not recommended.

Field preparation
Many major weed problems can be reduced by avoiding fields that are severely infested with weeds such as nightshades, little mallow, field bindweed, nutsedge, and parasitic dodder. Irrigation water can also be a source of weeds; keep canal banks free of weeds or install a weed screen on the inlets from canals. Avoid moving weed seed into fields on equipment. When equipment has been used in a weedy field, clean it before entering other fields.

Inverting the top soil profile (at least 12 inches deep) with a specialized moldboard plow (like the Kverneland plow) can effectively reduce nightshade and nutsedge populations by deeply burying seeds and tubers. In situations where this is not possible, such as with drip irrigation or conservation tillage systems, preirrigation or rainfall can germinate nightshade species before planting and the weed seedlings can be uprooted by a light cultivation or treatment with certain postemergence herbicides to reduce the population.

Soil solarization
Soil solarization can provide control of many soilborne diseases, nematodes, and weed pests. Solarization is primarily effective only in June, July, or August and needs to be applied for 4 to 6 weeks. For further information, contact your local farm advisor or see UC ANR Publication #21377, *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds.*

Soil fumigation
Metam sodium, metam potassium, and to a lesser degree 1,3-D or 1,3-D plus chloropicrin can provide control of many weeds and other soilborne pests. Adequate time is needed between fumigant application and crop transplanting to prevent phytotoxicity.

Herbicides
Herbicide applications made to fall or winter beds allow some fields to be planted early that could not otherwise be cultivated because of wet soil conditions. Adequate rainfall is necessary, however, to break down some fall-applied herbicides so that tomatoes planted in spring will not be injured. Ensure fallow bed herbicide applications to control annual weeds are made to clean cultivated beds. For fields that had weed problems during the season, especially perennial weeds such as field bindweed and little mallow, control weeds postharvest. Irrigate and then apply contact herbicides.

Some herbicides are best applied just before planting and incorporated into the soil. The entire bed top may be treated or band treatments applied over the seedline. Band treatments proportionally reduce the herbicide cost, usually require sprinkler irrigation for incorporation/activation, and usually reduce the risk of herbicide carryover into the next crop. An additional method of weed control, generally cultivation, will be required between crop rows. A postemergence weed treatment also may be necessary before planting to control weeds that have already emerged. Herbicide mixtures may be used to enhance weed control; select herbicidemixtures based on the benefits expected from increased weed control, the soil residual activity of the herbicides, and the degree of tomato selectivity.

WEED MANAGEMENT AT PLANTING
Planting dates
Manipulating planting dates might be used to take advantage of weed germination under different temperatures. For example, early plantings under cooler soil temperatures usually escape barnyardgrass competition during the tomato seedling stage. However, such decisions must balance weed control benefits against other, possibly negative, effects on tomato production.

With direct-seeded fields, rapid, even stand establishment allows the crop to better compete with weeds. Full tomato stands with good shading of the soil surface reduce the ability of late germinating weeds to compete. Stand establishment is optimized when soil temperatures are 70° to 80°F; under these conditions tomatoes generally emerge within 10 days. Under cool soil temperatures (50° to 60°F), emergence is often uneven and may take longer than 3 weeks.

Cultivation
A soil cap (2- to 4-inch mound of soil) over the seedline at planting can reduce the first flush of weeds competing with the crop seedlings. Discs, or other implements, form the soil cap just after planting. The cap is removed just after tomato seedlings germinate but before rapid elongation of the hypocotyl (emerging shoot). Rains could delay cap removal, leading to potential tomato stand loss. High temperatures during cap removal can cause

scalding of the emerging tomato seedlings and result in stand loss as well. However, under good conditions, weed seeds that germinate in the soil cap are destroyed when the cap is removed and fast-growing weeds that germinate in the original bed are often scraped off by the cap removal operation.

Transplanting

Transplanting into fields with high potential weed populations provides the crop an initial growth advantage over the weeds. Compared to direct seeding, more herbicides are available for transplants, especially preemergence herbicides, and in many cases, initial hand weeding can be eliminated or greatly reduced. Subsequent cultivations can further reduce weed populations along the sides of the planted row. Within the crop row, soil can be directed toward the base of the tomatoes, coveringsmall, emerged weeds and creating a dry mulch. As hybrid tomato varieties have become more expensive, transplanting has become a more widely used method, thus reducing herbicide inputs, hoeing, and thinning costs.

WEED MANAGEMENT AFTER PLANTING

Cultural practices

Preventing weeds from going to seed helps reduce weed populations in subsequent crops; this also applies to areas adjacent to the cropped fields. Irrigation water can also be a source of weeds; keep canal banks free of weeds or install a weed screen on the inlets from canals. Avoid moving weed seeds into fields on equipment. When equipment has been used in a weedy field, clean it before entering other fields.

Subsurface drip irrigation can also aid weed control by keeping bed tops dry. If tomatoes are transplanted, supplemental irrigation may not be needed initially. If tomatoes are direct seeded, a second irrigation system (furrow or sprinkler) may be needed to germinate the tomato seed, which also favors germination of weed seeds. Improve weed control by ensuring the crop is well established and free of emerged weeds before subsurface drip irrigation is used. Perennial weeds, such as field bindweed, are likely to remain a problem with this system.

With furrow irrigation systems, maintaining alternate row irrigation helps keep the bed tops from becoming overly wet while maintaining adequate soil moisture for the crop. By keeping the bed tops drier, less weeds are likely to germinate in the soil surface.

Cultivation and hand weeding

After crop emergence, mechanically cultivate close to the seedline to reduce the amount of hand-weeding needed. To avoid excessive competition with the tomatoes and to make removal easier, cultivate when weeds are small. Removing weeds in the seedling stage permits a shallow sweep cultivation, which helps to avoid bringing more weed seeds near the surface where they might germinate. When tomato seedlings are about 5 inches tall, cultivation tools can be arranged to create a dry layer of soil (dry mulch) onthe seedline to help prevent weed seeds from germinating and to smother small, emerged weeds. A single seedline per bed facilitates cultivation and is less costly to hand-weed than two seed lines.

Cultivation is effective at controlling many weeds in tomatoes; one exception is the parasitic weed dodder. Once dodder attaches to the tomato plant, it does not require connection with the soil and cannot be selectively controlled with cultivation. To reduce dodder problems, control broadleaf weeds that act asalternate hosts for dodder, allowing it to spread onto tomatoes. Especially eliminate tomato plants that have dodder attached at thinning and again 2 weeks later. As tomato plants grow, continue to look for dodder and if found, manage it to reduce seed production and further spread.

Nightshades can be controlled by hand-weeding, but it is not easy to distinguish nightshade from the tomato plant and often many are left in the tomato row. Other weeds that are not easily controlled with herbicides such as dodder, broomrape, and velvetleaf need to be rogued out. If they already have fruit or seeds, carry them out of the field if possible. Use hoeing, flaming or spot applications of foliar-applied herbicides to eliminate these weeds from fencerows and other areas around the field.

Flaming

In some situations, flaming can be used before tomato plants emerge or as a directed application after planting. Flaming the bed just before tomato emergence eliminates emerged weeds so the crop comes up without competition. Anadvantage to flamers over cultivation is that the soil is not disturbed so new weed seeds are not brought to the surface. Disadvantages of flaming include the high cost of fuel (usually propane) and the inability to control large weeds, especially grasses, without injuring the tomatoes.

Herbicides

After planting, postemergence herbicides can be applied to emerged weeds, either before or after the tomatoes have emerged. Layby treatments are usually applied as directed or shielded sprays on each side of the seedline and immediately incorporated with a power or ground-driven tiller, usually when the tomato crop is at the 6- to 8-true-leaf stage of growth.

Variable rate layby applications (applying full rate in the furrow and reduced rates next to the crop) can reduce herbicide cost with no loss in weed control or tomato yield. Variable rate treatments can be applied by changing the nozzle sizes on a standard layby setup, using one size in the furrows (e.g., 8002) and a smaller size (8001) near the crop.

SPECIAL WEED PROBLEMS (11/11)

DODDER

Dodder is a parasitic plant; its seedlings must attach to a suitable host to survive. In addition to tomatoes, other known hosts of dodder include safflower, sugarbeets, alfalfa, asparagus, honeydew melon, onions, carrots, nightshades, and numerous other broadleaf weeds. Rotations are generally not effective in eliminating dodder because it has a wide host range and its seeds can remain viable for years.However, rotation to nonhost crops such as cotton, corn, cereals, and garlic can help reduce seed numbers. The standard way to control dodder has been to destroy the host tomato plants as soon as dodder is observed. If dodder is flowering, remove the host plants from the field and burn them to kill the seed. Pendimethalin (Prowl H20) preemergence applications, which are registered in transplanted tomatoes only, have been shown to reduce dodder germination and emergence by 80%. Several tomato varieties, including Heinz 9492, 9553, 9888, 9992, 9997, 1100, CXD 233, and PX 665 have shown good resistance to dodder infestation, reducing seed production.

Most dodder germinates between March 1 and May 20, so late planting can help reduce problems with dodder.

FIELD BINDWEED

A deep-rooted perennial, field bindweed is difficult to control once it becomes established. Herbicides used in tomatoes are not effective against established plants; however, trifluralin (Treflan) as a layby treatment will control seedling field bindweed. Seedlings can be easily identified from established bindweed plants by the presence of cotyledons. Established plants require cultivation for control; in drip irrigated fields bindweed is becoming more problematic. By eliminating bindweed competition in tomatoes for 6 to 8 weeks after tomato emergence, full yields can be obtained. Field bindweed is best controlled after a cereal crop, where actively growing bindweed can be treated in fall with glyphosate (Roundup Weathermax, Glyphomax, Touchdown, etc).

In heavily infested fields a reclamation blade can be used to provide sufficient control to grow a crop of tomatoes relatively free of field bindweed. Use the reclamation blade following the harvest of a crop that dries or uses up the soil moisture to a depth of 18 to 20 inches. This method has been most effective following a cereal crop, safflower, or sugarbeets. Perform the blading during the summer months so that the severed rhizomes will dehydrate or desiccate. It takes about 10 to 12 months for the rhizome to regrow sufficiently from the 18- to 20-inch depth to adversely affect tomato plants grown in the field.

With the end of harvest, where there are high field bindweed populations, an herbicide control program in late fall can be effective if the bindweed has sufficient soil moisture to remain vigorous and flowering. Note plant-back restrictions of certain materials.

NIGHTSHADE

Related to tomatoes and potatoes, the nightshade family includes black nightshade, hairy nightshade, cutleaf nightshade, groundcherry, and several others. These annual weeds are resistant to many herbicides commonly used in tomatoes. Soil fumigation with metam sodium (Vapam) is an effective pre-plant treatment. Rimsulfuron (Matrix) provides control of most of the nightshade species when applied after seeding or transplanting as a preemergence treatment and incorporated with water from sprinklers or rain within 5 to 7 days of treatment. Rimsulfuron also provides postemergence control if the weeds are at the cotyledon stage. Nightshade seedlings can be partially controlled by a postemergence directed spray of metribuzin at the 5- to 6-true-leaf stage of direct-seeded or established tomato transplants. Rotating to crops where available herbicides control nightshade (e.g., Roundup Ready corn or cotton) helps to reduce seed levels in the soil.

Many weeds in the nightshade family, such as hairy, black, and cutleaf nightshade as well as groundcherries, germinate in the top 1 to 2 inches of soil. In fields heavily infested with seeds of these weeds, deep plowing with a well-adjusted moldboard plow (or Kverneland plow) can significantly reduce seed emergence. It is essential to completely invert the soil to bury the seeds below the germinating zone. In most cases, a standard or conventional moldboard plow does not invert the soil profile adequately to bury weed seeds uniformly.

NUTSEDGE

Nutsedge is a perennial that reproduces primarily through abundantly produced tubers. Tubers remainviable in the soil for several years until conditions are favorable for growth. Each tuber contains four to seven buds, each capable of producing a plant. Generally, only one bud will germinate on any tuber, but if it is destroyed by cultivation or herbicide treatment, a new plant will grow from one of the other buds. Partial suppression of

yellow nutsedge can be achieved with an application of metolachlor (Dual Magnum) at layby. Halosulfuron (Sandea) is effective in suppressing nutsedge after it emerges. Preplant use of metam sodium will also give some help with yellow nutsedge control in the tomato seedline. Cultivation can be used to help suppress nutsedge, but must be done by the 5- or 6-leaf stage or new tubers will have formed. Rotating to different crops, such as corn or beans, where available herbicides suppress nutsedge helps to avoid buildup of this weed.

Yellow and purple nutsedge rarely emerge from dormant tubers that are buried deeper than 4 to 6 inches. Therefore, during late fall, specialty plows (Wilcox or Kverneland) can be used to invert the soil to at least 12 inches deep to minimize the emergence of nutsedge in the tomato field. It is essential that the specialty plow completely invert the soil for this method of control to be effective.

COMMON AND SCIENTIFIC NAMES OF WEEDS (11/11)

Common Name	Scientific Name
Barnyardgrass	*Echinochloa crus-galli*
Bermudagrass	*Cynodon dactylon*
Bindweed, Field	*Convolvulus arvensis*
Broomrape	*Orobanche ramosa*
Canarygrasses	*Phalaris* spp.
Chickweed, Common	*Stellaria media*
Crabgrass, Large	*Digitaria sanguinalis*
Datura, Sacred	*Datura wrightii*
Dodders	*Cuscuta* spp.
Fleabane, Hairy	*Conyza bonariensis*
Goosefoot, Nettleleaf	*Chenopodium murale*
Groundcherries	*Physalis* spp.
Groundsel, Common	*Senecio vulgaris*
Horseweed	*Conyza canadensis*
Jimsonweed	*Datura stramonium*
Johnsongrass	*Sorghum halepense*
Knotweed, Prostrate	*Polygonum arenastrum*
Lambsquarters, Common	*Chenopodium album*
Lettuce, Prickly	*Lactuca serriola*
Lovegrasses	*Eragrostis* spp.
Mallow, Little (Cheeseweed)	*Malva parviflora*
Mustards	*Brassica* spp.
Nettle, Burning	*Urtica urens*
Nightshade, Black	*Solanum nigrum*
Nightshade, Hairy	*Solanum sarrachoides*
Nutsedge, Purple	*Cyperus rotundus*
Nutsedge, Yellow	*Cyperus esculentus*
Oat, Wild	*Avena fatua*
Pigweeds	*Amaranthus* spp.
Purslane, Common	*Portulaca oleracea*
Rocket, London	*Sisymbrium irio*
Shepherd's-Purse	*Capsella bursa-pastoris*
Sowthistles	*Sonchus* spp.
Sweetclovers	*Melilotus* spp.
Thistle, Russian	*Salsola tragus*
Tobacco, Indian	*Nicotiana quadrivalvis*
Tomatillo	*Physalis philadephica*
Velvetleaf	*Abutilon theophrasti*

SUSCEPTIBILITY OF WEEDS TO HERBICIDE CONTROL (11/11)

Pre- or Postemergence	FALL BED					PREPLANT							POSTPLANT								LAYBY				
	Pre		Postemergence			Preemergence							Pre		Postemergence						Preemergence				
	MTR	OXY	CAR	GLY	PAR*	13D/ CHL*	MEO	MEP*	MET*	NAP	PEN	TRI	MEO	RIM	CAR	CLE	HAL	MTR	RIM	SET	DCP	EPT	MEO	PEN	TRI
Mode of Action[1]	**5**	**14**	**14**	**9**	**22**	**–**	**15**	**–**	**–**	**15**	**3**	**3**	**15**	**2**	**14**	**1**	**2**	**5**	**2**	**1**	**3**	**8**	**15**	**3**	**3**
ANNUAL WEEDS																									
Broadleaves																									
Broomrape	N	—	—	C	N	—	—	—	C	N	—	P	—	—	—	N	N	N	—	N	—	N	—	—	P
Chickweed, Common	C	P	P	C	C	C	C	C	C	C	C	C	C	C	P	N	C	C	C	N	C	C	C	C	C
Dodders	N	C	P	C	C	—	N	—	C	N	P	N	N	N	P	N	P	N	P	N	P	P	N	P	N
Fleabane, Hairy	N	P	N	C	C	—	N	—	C	N	N	N	N	—	N	N	—	P	—	N	—	P	N	N	N
Goosefoot, Nettleleaf	C	C	—	C	C	C	P	C	C	C	C	C	P	P	—	N	C	C	P	N	C	C	P	C	C
Groundcherries	P	C	C	C	C	—	C	C	C	N	N	N	C	C	C	N	—	P	P	N	C	C	C	N	N
Groundsel, Common	P	C	—	C	C	C	N	C	C	C	N	N	N	C	—	N	C	C	P	N	N	C	N	N	N
Horseweed	—	P	N	C	C	—	N	—	C	N	N	N	N	—	N	N	—	C	—	N	—	P	N	N	N
Jimsonweed	N	C	—	C	C	—	—	—	C	N	N	N	—	—	—	N	—	N	—	N	—	C	—	N	N
Knotweed, Prostrate	N	C	—	C	P	—	N	—	C	C	C	C	N	C	—	N	—	P	P	N	P	P	N	C	C
Lambsquarters, Common	C	C	—	C	P	C	P	C	C	C	C	C	P	C	—	N	P	C	P	N	C	C	P	C	C
Lettuce, Prickly	C	C	—	C	C	—	N	C	C	C	N	N	N	P	—	N	N	P	P	N	—	C	N	N	N
Mallow, Little (Cheeseweed)	P	C	C	P	P	P	P	P	N	C	P	N	P	C	C	N	—	P	P	N	P	P	P	P	N
Mustards	C	C	P	C	C	—	N	C	C	P	P	N	N	C	P	N	C	C	C	N	P	N	N	P	N
Nettle, Burning	C	C	C	N	C	C	C	C	C	P	N	P	—	C	C	N	C	C	C	N	P	P	—	N	P
Nightshade, Hairy	P	C	C	C	C	—	C	C	C	N	P	N	C	C	C	N	N	P	P	N	P	C	C	P	N
Nightshade, Black	N	C	C	C	C	—	C	C	P	N	P	N	C	C	C	N	N	P	P	N	P	P	C	P	N
Pigweeds	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	N	C	C	P	N	C	C	C	C	C
Purslane, Common	P	C	N	C	C	C	C	C	C	C	C	C	C	C	N	N	P	P	C	N	C	C	C	C	C
Rocket, London	C	C	C	C	C	—	N	C	C	P	P	N	N	C	C	N	C	C	C	N	P	P	N	P	N
Shepherd's-Purse	C	C	P	C	C	—	P	C	C	P	P	N	P	C	P	N	P	C	C	N	P	P	P	P	N
Sowthistles	C	C	N	C	C	C	P	C	C	C	N	N	P	P	N	N	C	C	P	N	P	C	P	N	N
Sweetclovers	C	C	—	C	P	N	N	P	N	P	N	P	—	—	—	N	—	P	N	N	N	N	—	N	N
Thistle, Russian	C	P	—	C	P	—	P	P	C	P	P	C	P	P	—	N	—	P	P	N	C	N	P	P	C
Tobacco, Indian	—	C	—	C	C	—	—	—	C	N	N	N	—	—	—	N	—	N	—	N	—	C	—	N	N
Velvetleaf	P	C	C	C	C	—	P	P	C	N	N	N	P	P	C	N	C	C	P	N	N	P	P	N	N
Grasses																									
Barnyardgrass	P	P	N	C	C	C	C	C	C	C	C	C	C	C	N	C	N	P	C	C	C	C	C	C	C
Canarygrasses	—	P	N	C	C	—	C	C	C	C	C	C	C	—	N	C	N	N	—	C	C	C	C	C	C
Cereals, Volunteer	P	N	N	C	C	C	N	C	C	C	C	N	N	C	N	C	N	N	C	C	P	C	N	P	N
Crabgrass, Large	C	P	N	C	C	—	C	C	C	C	C	C	C	P	N	C	N	N	C	C	C	C	C	C	C
Lovegrasses	P	P	N	C	C	—	C	C	C	C	C	C	C	P	N	C	N	N	P	C	C	C	C	C	C
Oat, Wild	P	P	N	C	P	—	N	C	C	C	P	N	N	P	N	C	N	N	P	C	P	C	N	P	C
PERENNIAL WEEDS																									
Seedlings																									
Bermudagrass	N	N	N	C	C	C	N	C	C	C	C	N	N	N	N	C	N	N	—	C	C	C	N	C	C
Bindweed, Field	N	N	C	C	C	N	N	N	C	N	N	N	P	N	C	N	N	N	P	N	N	—	P	N	C
Johnsongrass	N	N	N	C	C	—	C	—	C	P	C	C	C	P	N	C	N	N	P	C	C	C	C	C	C
Established																									
Bermudagrass	N	N	N	C	N	T	N	T	P	N	N	N	N	N	N	P	N	N	N	P	N	N	N	N	N
Bindweed, Field	N	N	P	C	N	N	N	T	P	N	N	N	—	P	P	N	—	N	P	N	N	N	—	N	N
Datura, Sacred	N	N	—	C	P	—	—	—	N	N	N	N	—	—	—	—	N	P	—	N	—	P	—	N	N
Johnsongrass	N	N	N	P	N	—	N	N	P	N	N	N	N	N	N	P	N	N	N	C	N	C	N	N	N
Nutsedge, Purple	N	N	N	P	N	—	N	P	N	N	N	N	N	P	N	N	C	N	N	N	N	C	N	N	N
Nutsedge, Yellow	P	N	N	P	N	P	P	P	P	P	N	N	P	P	N	N	P	N	N	N	N	C	P	N	N

Pre- or	FALL BED					PREPLANT							POSTPLANT								LAYBY				
Postemergence	Pre		Postemergence			Preemergence							Pre		Postemergence						Preemergence				
	MTR	OXY	CAR	GLY	PAR*	13D/ CHL*	MEO	MEP*	MET*	NAP	PEN	TRI	MEO	RIM	CAR	CLE	HAL	MTR	RIM	SET	DCP	EPT	MEO	PEN	TRI
Mode of Action[1]	**5**	**14**	**14**	**9**	**22**	**–**	**15**	**–**	**–**	**15**	**3**	**3**	**15**	**2**	**14**	**1**	**2**	**5**	**2**	**1**	**3**	**8**	**15**	**3**	**3**

C = control P = partial control N = no control T = top kill only — = no = information

13D/CHL = 1,3-dichloropropene/chloropicrin* (Telone)
CAR = carfentrazone (Shark)
CLE = clethodim (Select Max)
DCP = DCPA (Dacthal)
EPT = EPTC (Eptam)
GLY = glyphosate (Roundup, Touchdown)
HAL = halosulfuron (Sandea)
MEO = metolachlor (Dual Magnum)
MEP = metam potassium* (K-Pam HL)
MET = metam sodium* (Vapam, etc.)
MTR = metribuzin (Metribuzin 75, etc.)
NAP = napropamide (Devrinol)
OXY = oxyfluorfen (Goal)
PAR = paraquat* (Gramoxone Inteon)
PEN = pendimethalin (Prowl H20)
RIM = rimsulfuron (Matrix)
SET = sethoxydim (Poast)
TRI = trifluralin (Treflan, etc.)

*Permit required from county agricultural commissioner for purchase or use.

[1]Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode-of-action numbers are useful in planning mixtures or rotations of herbicides with different modes of action. For more information, see http://www.hracglobal.com.

HERBICIDE TREATMENT TABLE (11/11)

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)

When choosing an herbicide, consider information relating to environmental impact. Not all registered pesticides are listed. Always read the label of the product being used.

FALL BEDS

Before weeds emerge

A. METRIBUZIN — 0.25–0.5 lb a.i.
(Metribuzin 75) — 0.33–0.66 lb — 12 — —
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Used generally for broadleaf weeds. Rate is dependent on soil type: apply low rates when soil organic matter is less than 2% and high rates when organic matter exceeds 2%. Do not plant within 4 months of application to prevent crop injury. Irrigation or rainfall (0.5 inch) is needed to activate metribuzin. It has reduced activity under cool, wet, cloudy conditions. Low amounts of rainfall or irrigation can reduce chemical breakdown of metribuzin leading to crop injury. Do not disturb the soil surface after application as this reduces weed control. Note rotation restrictions before using this herbicide. Do not use in Kern County, the Coachella Valley, Imperial Valley, and Blythe, or in highly alkaline or light sandy soils.

B. OXYFLUORFEN — 0.25–0.5 lb a.i.
(Goal 2XL) — 1–2 pt — 24 — —
(GoalTender) — 0.5–1 pt — 24 — —
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: Provides control of annual broadleaves both before and after they emerge. Rate depends on weed size, but the rate used also determines the minimum period between treatment and planting: 60 days for the low rate and 120 days for the high rate. The minimum period between treatment and transplanting is 30 days. Incorporate with 2 inches of irrigation water and do not disturb soil until planting time. Work beds with a rolling cultivator or similar tool to a depth of 2.5 inches before planting to avoid crop injury or stand loss. Once beds have been worked before planting, the herbicide is no longer effective. However, crop injury can result if beds are not thoroughly worked before planting, or if seedling tomatoes are stressed. This herbicide lasts 4 to 8 weeks in the soil and has a 10-month plantback restriction for nonlabeled crops.

After weeds emerge

A. PARAQUAT* — 0.5–1 lb a.i.
(Gramoxone Inteon) — 2–4 pt — 24 — 30
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 22
COMMENTS: A nonselective, foliar herbicide without residual activity that is applied as a band treatment over the crop row or as a broadcast treatment before, during, or after tomato planting but *before* crop emergence. Controls only emerged weeds. Controls annual weeds and provides some suppression of perennials. Apply when weeds are succulent and about 1 to 4 inches high; larger weeds are less affected. Apply in 10 to 60 gal water/acre (5 gal by air) with a nonionic surfactant added at the rate of 8 to 32 oz/100 gal. Use the high surfactant rate with cereals and heavy weed infestations. Do not apply when weather conditions favor drift.

B. GLYPHOSATE
(Roundup) — annuals: 0.38–1.406 lb a.i. perennials: 0.5–4.53 lb a.i. — 4 — 14
(Touchdown) — perennials: 0.5–3.75 lb a.i. — 12 — 0
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9
COMMENTS: A nonselective, foliar herbicide that is used at least 3 days before transplanting or up to the time of crop emergence. For direct-seeded tomatoes, weeds must be emerged and actively growing. Rate depends on weed species and to some extent on size. Annual weeds are best controlled when small (less than 4 inches) and not water stressed; control is poor when weeds exceed the maximum size indicated on the label. Apply in 3 to 20 gal water. Provides good annual weed control and some suppression of perennial weeds. Control of perennials improves with late summer or fall applications during noncrop periods when perennials are actively growing. Higher application rates are needed for perennial control.

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)
C. CARFENTRAZONE	0.031 lb a.i.		
(Shark EW)	2 fl oz	12	0

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: Preplant burndown of weeds for transplants only. A nonselective, foliar herbicide without residual activity that is applied as a band treatment over the crop row or as a broadcast treatment at least one day before transplanting. Controls only emerged weeds. Controls annual weeds and provides some suppression of perennials. Apply when weeds are succulent and about 1 to 4 inches high; larger weeds are less affected. Apply in 10 gal water/acre (3 gal by air) with a nonionic surfactant at 0.25% v/v, or methylated seed oil or crop oil concentrate at 1 to 2% v/v. Do not apply whenweather conditions favor drift.

PREPLANT

Before weeds emerge

A. METAM SODIUM*	159.75–319.5 lbs a.i.		
(various trade names, 42%)	37.5–75 gal	See label	—
. . . or . . .			
METAM POTASSIUM*			
(K-PAM HL)	30–62 gal	See label	—

COMMENTS: A liquid soil fumigant that controls many weeds, but is used mainly for nightshade control and nutsedge suppression. Also suppresses nematodes and disease. Beds must be free of large clods and the soil should be moistened by rainfall or irrigation before application. Soil temperatures should be between 40° to 90°F at a 3-inch depth. Broadcast rate is 50 to 75 gal/acre, but typically a 6-inch band is treated using 5 to 7.5 gal/crop acre (single row planting of tomatoes). Applications are made using a spray blade cutting 2 to 3 inches below the soil surface, depending on soil moisture. Disc hillers follow directly behind the spray blade to form a 3- to 5-inch soil cap over the treated area. After 7 to 14 days, depending on the rate applied, the soil caps are removed and allowed to air. The label requires a 14-day preplant interval between application and planting. Avoid moving untreated soil into the banded area. This treatment is effective against nightshade and many other weeds. Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.

B. METOLACHLOR	0.95–1.59 lb a.i.		
(Dual Magnum)	1–1.67 pt	24	60

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENTS: Suppresses nutsedge and nightshades. Apply preplant for transplants only. Incorporate or apply as a surface application before transplanting. If incorporated, make certain to place transplant roots below the treated soil or injury may occur. Does not control emerged weeds. Rate depends on soil texture. Metolachlor plus trifluralin or pendimethalin tank mixes are particularly effective.

C. NAPROPAMIDE	1–2 lb a.i.		
(Devrinol 50DF)	2–4 lb	24	—
(Devrinol 2EC)	2–4 qt	24	—

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENTS: Controls most annual grasses and broadleaves. Rate is dependent on soil type. Incorporation to a depth of 2 to 3 inches is needed soon after application to prevent loss. Band applications are frequently used to reduce costs. If napropamide is used on fall beds, do not treat a second time with this material.

D. TRIFLURALIN	0.5–1 lb a.i.		
(Treflan HFP, 4EC)	1–2 pt	12	—
(Trilin 10G)	5–10 lb	12	—

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Can be applied preplant for transplants only. Rate is dependent on soil type. Trifluralin is volatile and must be immediately incorporated to avoid loss. Keep treated soil above the roots. Apply in 5 to 40 gal water/acre and incorporate into the top 2 to 3 inches of the bed before transplanting. It provides good season-long control of many annual grasses and broadleaves as well as partial control of seedling field bindweed.

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)
E. PENDIMETHALIN	0.475–1.42 lb a.i.		
(Prowl H20)	1–3 pt	24	21
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3			
COMMENTS: Provides good, season-long control of many annual grasses and broadleaves as well as partial control of dodder. Can be applied preplant for transplants only. Rate is dependent on soil type. Apply in a minimum of 10 gal water/acre by ground or 5 gal water/acre by aircraft. Rainfall, sprinkler irrigation, or shallow mechanical incorporation after application is required to move the herbicide into the upper soil layers where weeds germinate. Do not apply more than 3 pt/acre. Use allowed under a supplemental label.			
F. 1,3-DICHLOROPROPENE*			
(Telone EC)	Label rates	120	—
. . . or . . .			
1,3-DICHLOROPROPENE/CHLOROPICRIN*			
(Telone C35)	Label rates	120	—
COMMENTS: Efficacy affected by soil texture, moisture, temperature, and percent organic matter. Fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Fumigate only as a last resort when other management strategies have not been successful or are not available.			
POSTPLANT			
Before weeds emerge			
A. RIMSULFURON	0.5–1 oz a.i.		
(Matrix 25DF)	2–4 oz	4	45
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 2			
COMMENTS: Provides good control of many weeds including most nightshade species, pigweeds, lambsquarters among others. Length of control may be reduced under cool, wet conditions. Apply treatment after tomato seeding or transplanting. Apply using a ground application in 10 to 40 gal water/acre. If weeds have already emerged, add a nonionic surfactant at a rate of 0.25% v/v. Rainfall or sprinkler irrigation (0.5–1 inch) is needed for activation within 5 days of treatment.			
B. METOLACHLOR	0.95–1.59 lb a.i.		
(Dual Magnum)	1–1.67 pt	24	90
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15			
COMMENTS: Will provide control of yellow nutsedge during crop establishment. May be applied to postdirected transplants after the first settling rain or irrigation in a minimum of 20 gal water/acre. Minimize contact with tomato plants. May be applied to direct-seeded tomatoes that are at least 4 inches tall. Apply in a minimum of 20 gal water/acre and minimize contact with plants. Rate depends on soil texture.			
C. HALOSULFURON	0.37–0.75 oz a.i.		
(Sandea)	0.5–1 oz	12	30
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 2			
COMMENTS: Can be used preemergence in transplanted tomatoes to control nutsedge. Tomatoes may be transplanted 7 days after treatment unless conditions demonstrate safety at an earlier interval. Take care to prevent movement of treated soil during the transplant process.			
POSTPLANT			
After weeds emerge			
A. CLETHODIM	0.068–0.2425 lb a.i.		
(Select 2E)	6–16 fl oz	24	20
(Select Max)	9–32 fl oz	24	20
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1			
COMMENTS: Controls actively growing small grasses except for bromes and fescues. Use a nonionic surfactant at a rate of 0.25% v/v in Select Max or a crop oil concentrate at a rate of 1% v/v in Select 2E. Apply to annual bluegrass at 4-leaf stage. Repeat treatments necessary for perennial grasses. Apply in at least 30 gal water/acre.			

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)
B. HALOSULFURON	0.37–0.75 oz a.i.		
(Sandea)	0.5–1 oz	12	30

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 2
COMMENTS: For use on seed and transplant tomatoes for the control of nutsedge. Apply over the top of direct-seeded tomatoes from the 4-true leaf stage through first bloom. Make applications to transplanted tomatoes at least 14 days after transplanting but before first bloom. Following bloom, applications must be made either as a directed spray or with shields to minimize contact with the crop. Injury may result if the spray contacts the foliage. Minimum (0.37 oz a.i.) and maximum (0.50 oz a.i.) rates are lower for direct-seeded tomatoes grown in Riverside and Imperial counties than those grown in other areas of California where the minimum rate is 0.5 oz a.i. and the maximum rate is 0.75 oz a.i. Use of 0.25 to 0.5% v/v of nonionic surfactant is recommended. Use of crop oil concentrate or silicone surfactants is not recommended because of increased risk of injury. Do not apply halosulfuron if a soil application of an organophosphate insecticide has been made. Do not apply a foliar organophosphate insecticide within 21 days before or 7 days after any halosulfuron treatment.

C. METRIBUZIN			
(Metri 4F)	0.5–1 lb a.i. or 1–2 pt	12	7
(Metribuzin 75 DF)	0.2475–0.9975 lb a.i. or 0.33–1.33 lb	12	7

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Used primarily for black nightshade control on loam or clay loam soils. Has both pre- and postemergence activity. Can be applied as a broadcast spray at rates up to 0.5 lb a.i./acre or as a directed spray at rates up to 1 lb a.i./acre. Rate is dependent on the weed species and soil type and can be applied as a single treatment or split into 2 treatments. If split, the treatments must be at least 14 days apart, with the total applied in a year not exceeding 1 lb a.i./acre for the 4F formulation and 0.9975 lb a.i. for the DF formulation. Apply in 20 to 75 gal water/acre as a directed spray to avoid contact with terminals of the tomato plant. Do not use with a surfactant, with other pesticides as a tank mix, or within 24 hours of other pesticide applications. Tomatoes should be 6 to 10 inches tall or the 6-true-leaf stage. Avoid spraying when tomatoes are stressed by cool, cloudy, wet weather or by drought as injury could occur. Do not use in Kern County. Observe restrictions on rotational crops.

D. RIMSULFURON	0.25–0.5 oz a.i.		
(Matrix 25DF)	1–2 oz	4	45

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 2
COMMENTS: Provides good control of many weeds including most nightshades but only partial control of black nightshade. Single or multiple applications may be made per season, but the total applied must not exceed 4 oz product/acre/year. The maximum rate for preemergence use is 2 oz/acre, but up to 4 oz/acre can be used if both preemergence (2 oz) and postemergence (2 oz) treatments are made or if two postemergence treatments are made (2 oz + 2 oz). Tomatoes can be treated as early as the cotyledon stage. Use a nonionic surfactant at a rate of 0.25% v/v, and apply in 10 to 40 gal water/acre. Temporary yellowing of tomatoes may result following treatment but generally disappears after 1 to 2 weeks.

E. SETHOXYDIM	0.28 lb a.i.		
(Poast 1.5EC)	1.5 pt	12	20

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
COMMENTS: Selective herbicide for control of grassy weeds. Has postemergence activity only. Annual and perennial grasses must be at the proper size, well watered, and actively growing for good control. This treatment can be repeated up to 3 times/season; be sure to observe the preharvest interval. Apply in 10 to 20 gal water plus a crop oil concentrate at the rate of 1 qt/acre. Do not treat transplanted tomatoes within 14 days of transplanting. Labels recommend not cultivating within 5 days before application or within 7 days following application. Do not apply with any other pesticide or fertilizer.

F. CARFENTRAZONE	0.031 lb a.i.		
(Shark EW)	2 fl oz	12	0

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: COMMENTS: Controls annual weeds and provides some suppression of perennials. Controls only emerged weeds. Only hooded applications are permitted, as contact with tomatoes will cause injury. A nonselective, foliar herbicide without residual activity. Apply when weeds are succulent and about 1 to 4 inches high; larger weeds are less affected. Apply in 10 gal water with a nonionic surfactant at 0.25% v/v, or methylated seed oil or crop oil concentrate at 1 to 2% v/v.

Common name (example trade name)	Amount per acre	R.E.I.‡ (hours)	P.H.I.‡ (days)
LAYBY			
Before Weeds Emerge			
A. TRIFLURALIN	0.5–1 lb a.i.		
(Treflan HFP)	1–2 pt	12	0
(Trilin 10G)	5–10 lb	12	0
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3			
COMMENTS: Provides good season-long control of annual grasses and many broadleaves as well as partial control of seedling field bindweed. Rate is dependent on soil type. Apply as a directed spray to the soil between rows and beneath tomato plants or as a shielded spray, but not over the top of plants as yields may be reduced. Trifluralin is volatile and must be immediately incorporated to avoid loss. Apply in 5 to 40 gal water/acre and incorporate into the top 2 to 3 inches of the bed.			
B. EPTC	3.0625 lb a.i.		
(Eptam 7EC)	3.5 pt	12	21
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 8			
COMMENTS: EPTC provides good control of hairy nightshade, johnsongrass seedlings, yellow nutsedge and many annuals. Apply as a directed spray at layby and immediately incorporate. Do not apply within 2 inches of the crop row. Tomatoes should be at least 3 to 4 inches tall at the time of this application. Do not irrigate for at least 5 days after application to avoid crop injury. Do not use this herbicide on sandy soils. This herbicide is registered for Northern California only (Fresno County and north). Allow 90 days between application and a grain rotation.			
C. DCPA	4.5–10.5 lb a.i.		
(Dacthal)	6–14 lb	12	0
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3			
COMMENTS: Gives partial control of dodder when applied before dodder emerges. Apply as a banded treatment when seeded tomatoes are 4 to 6 inches tall or 4 to 6 weeks after transplanting. Cultivate soil before treatment if weeds have emerged. Apply during warm, dry weather.			
D. METOLACHLOR	0.95–1.59 lb a.i.		
(Dual Magnum)	1–1.67 pt	24	90
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15			
COMMENTS: Provides control of yellow nutsedge during crop establishment. May be applied to postdirected transplants after the first settling rain or irrigation in a minimum of 20 gal water/acre. May be applied to direct-seeded tomatoes that are at least 4 inches tall. Apply in a minimum of 20 gal water/acre and minimize contact with plants. Rate depends on soil texture.			
E. PENDIMETHALIN	0.475–1.42 lb a.i.		
(Prowl H20)	1–3 pt	24	21
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3			
COMMENTS: Provides good, season-long control of many annual grasses and broadleaves as well as partial control of dodder. Can be applied as a post-directed spray for established direct-seeded tomatoes and transplanted tomatoes. Avoid contact with the foliage or stems. Rate is dependent on soil type. Apply in a minimum of 10 gal water/acre by ground. Rainfall, sprinkler irrigation, or shallow mechanical incorporation after application is required to move the herbicide into the upper soil layers where weeds germinate. Do not apply more than 3 pt/acre. Use allowed under a supplemental label.			

‡ Restricted entry interval (R.E.I.) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (P.H.I.) is the number of days from treatment until harvest can take place. In some cases the R.E.I. exceeds the P.H.I. The longer of these two intervals is the minimum time that must elapse before harvest may take place.

— Not applicable or unknown.

1 Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode of action numbers are useful in planning mixtures or rotations of herbicides with different modes of action. For more information, see http://www.plantprotection.org/HRAC/.

* Permit required from county agricultural commissioner for purchase or use.

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Precautions for Using Pesticides

Pesticides are poisonous and must be used with caution. **READ THE LABEL BEFORE OPENING A PESTICIDE CONTAINER.** Follow all label precautions and directions, including requirements for protective equipment. Apply pesticides only on the crops or in the situations listed on the label. Apply pesticides at the rates specified on the label or at lower rates if suggested in this publication. In California, all agricultural uses of pesticides must be reported. Contact your county agricultural commissioner for further details. Laws, regulations, and information concerning pesticides change frequently. This publication reflects legal restrictions current on the date next to each pest's name.

Legal responsibility

The user is legally responsible for any damage due to misuse of pesticides. Responsibility extends to effects caused by drift, runoff, or residues.

Transportation

Do not ship or carry pesticides together with food or feed in a way that allows contamination of the edible items. Never transport pesticides in a closed passenger vehicle or in a closed cab.

Storage

Keep pesticides in original containers until used. Store them in a locked cabinet, building, or fenced area where they are not accessible to children, unauthorized persons, pets, or livestock. **DO NOT** store pesticides with foods, feed, fertilizers, or other materials that may become contaminated by the pesticides.

Container disposal

Dispose of empty containers carefully. Never reuse them. Make sure empty containers are not accessible to children or animals. Never dispose of containers where they may contaminate water supplies or natural waterways. Consult your county agricultural commissioner for correct procedures for handling and disposal of large quantities of empty containers.

Protection of nonpest animals and plants

Many pesticides are toxic to useful or desirable animals, including honey bees, natural enemies, fish, domestic animals, and birds. Crops and other plants may also be damaged by misapplied pesticides. Take precautions to protect nonpest species from direct exposure to pesticides and from contamination due to drift, runoff, or residues. Certain rodenticides may pose a special hazard to animals that eat poisoned rodents.

Posting treated fields

For some materials, *restricted entry intervals* are established to protect field workers. Keep workers out of the field for the required time after application and, when required by regulations, post the treated areas with signs indicating the safe re-entry date. Check with your county agricultural commissioner for latest restricted entry interval.

Preharvest intervals

Some materials or rates cannot be used in certain crops within a specified time before harvest. Follow pesticide label instructions and allow the required time between application and harvest.

Permit requirements

Many pesticides require a permit from the county agricultural commissioner before possession or use. When such materials are recommended, they are marked with an asterisk (*) in the treatment tables or chemical sections of this publication.

Maximum residue levels

Before applying pesticides to crops destined for export, check maximum residue levels (MRLs) of importing country at http://www.mrldatabase.com.

Processed crops

Some processors will not accept a crop treated with certain chemicals. If your crop is going to a processor, be sure to check with the processor before applying a pesticide.

Crop injury

Certain chemicals may cause injury to crops (phytotoxicity) under certain conditions. Always consult the label for limitations. Before applying any pesticide, take into account the stage of plant development, the soil type and condition, the temperature, moisture, and wind. Injury may also result from the use of incompatible materials.

Personal safety

Follow label directions carefully. Avoid splashing, spilling, leaks, spray drift, and contamination of clothing. **NEVER** eat, smoke, drink, or chew while using pesticides. Provide for emergency medical care **IN ADVANCE** as required by regulation.