

## PEST MANAGEMENT GUIDELINES FOR AGRICULTURE

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### The UC IPM Pest Management Guidelines are available from:

- **Online:** <http://ipm.ucanr.edu>
- **UC Cooperative Extension:** County Offices
- **University of California**  
**ANR Communication Services**  
 2801 Second Street  
 Davis, CA 95618-7779  
 530-750-1213; 800-994-8849

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

**Note to readers:** These guidelines represent the best information currently available to the authors and are intended to help you make the best choices for an IPM program. Not all formulations or registered pesticides are mentioned. Always read the label and check with local authorities for the most up-to-date information regarding registration and restrictions on pesticide use. Check with your agricultural commissioner for latest restricted entry intervals.

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To be used with *Integrated Pest Management for Strawberries*, UC ANR Publication 3351.

# Strawberry Year-Round IPM Program (Reviewed 7/18)

## ANNUAL CHECKLIST



Use these guidelines for a monitoring-based IPM program to effectively manage pests, while reducing the risks of pesticides on the environment and human health.

When a pesticide application is considered, review the **Pesticide Application Checklist** for information on how to minimize the risks of pesticide use to water and air quality. Water quality can be impaired when pesticides drift into waterways or when they move off-site. Air quality can be impaired when pesticide applications release volatile organic compounds (VOCs) into the atmosphere.

This year-round IPM program covers the major pests of strawberry fruit-production fields in California. Pest management activities for strawberry nurseries are discussed only as they impact pest problems in the field. Details on carrying out each practice and information on additional pests can be found in the Strawberry Pest Management Guidelines. Track your progress through the year with this annual checklist form. Color photo identification sheets and examples of monitoring forms can be found online at <http://ipm.ucanr.edu/FORMS>.

✓ Done	Preplant Mitigate pesticide effects on air and water quality.									
	Work with the nursery to obtain transplants of the desired cultivar and certification level.									
	Survey previous crop and adjacent areas <ul style="list-style-type: none"> <li>• Weeds: keep records (<i>example form available online</i>)</li> <li>• Lygus bug host plants</li> <li>• Whiteflies</li> <li>• Vertebrate pests</li> </ul>									
	Review the cropping history of the field.									
	Analyze soil for nutrients and salts; consider an application of slow-release fertilizer.									
	Consider analyzing irrigation water for salinity and nitrogen content.									
	Consider soil treatments for soilborne pests and weeds. <ul style="list-style-type: none"> <li>• Soil fumigation (broadcast or drip applied)</li> <li>• Soil solarization (only in non-coastal, warmer regions)</li> <li>• Possible alternative methods such as anaerobic soil disinfestation or steam treatments</li> </ul>									
	Prepare the field by making sure it is properly graded with good drainage.									
	Shape beds to minimize water retention on bed tops.									
	Consider visiting the transplant nursery in the last month of the propagation cycle (before it gets cold) to evaluate nursery fields for: <ul style="list-style-type: none"> <li>• Pest and pathogen problems that may be carried on transplants:               <table style="width: 100%; border: none;"> <thead> <tr> <th style="text-align: left; width: 33%;">Invertebrates</th> <th style="text-align: left; width: 33%;">Diseases</th> <th style="width: 33%;"></th> </tr> </thead> <tbody> <tr> <td>◦ Spider mites</td> <td>◦ Angular leaf spot</td> <td>◦ Phytophthora</td> </tr> <tr> <td>◦ Cyclamen mite</td> <td>◦ Anthracnose</td> <td>◦ Powdery mildew</td> </tr> </tbody> </table> </li> <li>• Uniformity in planting, indicating possible disease or plant quality issues</li> <li>• Pesticide usage</li> </ul>	Invertebrates	Diseases		◦ Spider mites	◦ Angular leaf spot	◦ Phytophthora	◦ Cyclamen mite	◦ Anthracnose	◦ Powdery mildew
Invertebrates	Diseases									
◦ Spider mites	◦ Angular leaf spot	◦ Phytophthora								
◦ Cyclamen mite	◦ Anthracnose	◦ Powdery mildew								
	Apply herbicides, if needed, before applying mulch.									
	Apply plastic mulch appropriate to your needs for: <ul style="list-style-type: none"> <li>• Weed control</li> <li>• Managing soil temperature</li> <li>• Controlling plant size</li> </ul>									

✓ Done	<h2>Planting</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>
	Inspect transplants for gray mold, uniformity, quality, and proper root length. Follow proper procedures for placement of strawberry transplants.
	Consider fungicide dips and water wash to reduce fungal diseases. <ul style="list-style-type: none"> <li>• Anthracnose</li> <li>• Phytophthora crown rot</li> <li>• Red stele</li> <li>• Gray mold</li> </ul>
	Consider monitoring salinity of irrigation water.
	Irrigate as needed.
	Apply fertilizer at planting if preplant application was not made.
	Confirm correct planting depth and root orientation of transplants.
	Plant dust control barriers (e.g., ryegrass, cilantro, or other plant or plant mix suitable for dust control) at the ends of beds and along field edges as needed.

✓ Done	<h2>Prebloom</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>
	Confirm correct planting, note any need for replanting.
	Monitor for spider mites and caterpillars. <ul style="list-style-type: none"> <li>• Keep records (<i>example form available online</i>), and manage as needed according to the Pest Management Guidelines.</li> </ul>
	Monitor for other insects and mites and flag locations with problems: <ul style="list-style-type: none"> <li>• Aphids</li> <li>• Cyclamen mite</li> <li>• Whiteflies</li> </ul>
	Look for diseases and flag locations with problems: <ul style="list-style-type: none"> <li>• Angular leaf spot</li> <li>• Anthracnose</li> <li>• Common leaf spot</li> <li>• Leaf blotch</li> <li>• Phytophthora crown and root rot</li> <li>• Powdery mildew</li> <li>• Red stele root rot</li> </ul>
	Look for vertebrate pests and flag locations with problems: <ul style="list-style-type: none"> <li>• Deer</li> <li>• Ground squirrels</li> <li>• Moles</li> <li>• Pocket gophers</li> <li>• Voles</li> </ul>
	Survey for weed emergence. <ul style="list-style-type: none"> <li>• Apply preemergence herbicide as needed according to the Pest Management Guidelines.</li> <li>• Handweed as needed.</li> </ul>
	Remove runners in summer plantings as needed.
	Consider monitoring salinity of irrigation water.
	Monitor soil moisture and irrigate as needed.
	Apply fertilizer as needed.

✓ Done	<h2>Flowering to first harvest</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>
	Monitor for spider mites and caterpillars (cutworms, armyworms).

	<ul style="list-style-type: none"> <li>• Keep records (<i>example form available online</i>), and manage as needed according to the Pest Management Guidelines.</li> </ul>
	<p>Monitor lygus bug in Central Coast plantings and Southern California summer plantings.</p> <ul style="list-style-type: none"> <li>• Survey weed hosts.</li> <li>• Consider calculating degree-days to time egg hatch.</li> </ul> <p>Keep records (<i>example form available online</i>) and manage as needed according to the Pest Management Guidelines.</p>
	<p>Monitor for other insects and mites and flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Aphids</li> <li>• Thrips</li> <li>• Cyclamen mite</li> <li>• Whiteflies</li> </ul>
	<p>Look for diseases and flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Angular leaf spot</li> <li>• Leaf blotch</li> <li>• Anthracnose</li> <li>• Phytophthora crown and root rot</li> <li>• Common leaf spot</li> <li>• Red stele root rot</li> <li>• Fusarium wilt</li> <li>• Verticillium wilt</li> </ul>
	<p>Manage diseases as needed according to the Pest Management Guidelines.</p> <ul style="list-style-type: none"> <li>• Botrytis fruit rot</li> <li>• Powdery mildew</li> </ul>
	<p>Look for vertebrate pests and flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Deer</li> <li>• Pocket gophers</li> <li>• Ground squirrels</li> <li>• Voles</li> <li>• Moles</li> </ul>
	<p>Survey for weed emergence; manage as needed according to the Pest Management Guidelines.</p>
	<p>Consider monitoring salinity of irrigation water.</p>
	<p>Monitor soil moisture and irrigate as needed.</p>
	<p>Apply fertilizer as needed.</p>

✓ Done	<h2>Harvest</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>
	<p>Monitor weekly for lygus bug.</p> <ul style="list-style-type: none"> <li>• If using degree-days, continue the calculations.</li> <li>• Keep records (<i>example form available online</i>).</li> </ul>
	<p>Monitor for spider mites and caterpillars.</p> <ul style="list-style-type: none"> <li>• Keep records, and manage as needed according to the Pest Management Guidelines.</li> </ul>
	<p>Monitor for other insects and mites and flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Aphids</li> <li>• Vinegar flies</li> <li>• Cyclamen mite</li> <li>• Spotted-wing drosophila</li> <li>• Thrips</li> <li>• Whiteflies</li> </ul>
	<p>Look for diseases and flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Angular leaf spot</li> <li>• Leaf blotch</li> <li>• Anthracnose</li> <li>• Macrophomina crown rot</li> <li>• Common leaf spot</li> <li>• Phytophthora crown rot</li> <li>• Fusarium wilt</li> <li>• Red stele root rot</li> <li>• Verticillium wilt</li> </ul>
	<p>Manage diseases as needed according to the Pest Management Guidelines.</p> <ul style="list-style-type: none"> <li>• Botrytis fruit rot</li> <li>• Powdery mildew</li> </ul>

✓ Done	<h2>Harvest</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>
	<p>Look for vertebrate pests, flag locations with problems:</p> <ul style="list-style-type: none"> <li>• Deer</li> <li>• Ground squirrels</li> <li>• Moles</li> <li>• Pocket gophers</li> <li>• Voles</li> </ul>
	Survey for weed emergence; manage as needed according to the Pest Management Guidelines.
	Remove and discard decayed fruit and fruit with water damage.
	Look for bird damage on fruit, especially in locations with a history of bird presence.
	Consider monitoring salinity of irrigation water.
	Monitor soil moisture and irrigate as needed.
	Apply fertilizer as needed.

✓ Done	<h2>Postharvest</h2> <p><b>Mitigate pesticide effects on air and water quality.</b></p>		
	Consider rotation crops for reducing pest problems and improving soil structure, organic matter, and water penetration.		
	Consider a cover crop to reduce runoff and erosion.		
	Thoroughly work-in crop residue immediately after harvest, allowing it to completely decompose before the next strawberry crop.		
	<p>Analyze field records for pest problems:</p> <table style="width: 100%; border: none;"> <tr> <td style="vertical-align: top;"> <p><b>Insects</b></p> <ul style="list-style-type: none"> <li>• Aphids</li> <li>• Beet armyworm</li> <li>• Cabbage looper</li> <li>• Cutworms</li> <li>• Cyclamen mite</li> <li>• Spider mites</li> <li>• Whiteflies</li> </ul> </td> <td style="vertical-align: top;"> <p><b>Diseases</b></p> <ul style="list-style-type: none"> <li>• Angular leaf spot</li> <li>• Anthracnose</li> <li>• Botrytis fruit rot</li> <li>• Fusarium wilt</li> <li>• Macrophomina crown rot</li> <li>• Phytophthora crown and root rot</li> <li>• Powdery mildew</li> <li>• Red stele</li> <li>• Verticillium wilt</li> </ul> </td> </tr> </table> <p>Analyze how management strategies affected yield to plan a management program for the next strawberry crop.</p>	<p><b>Insects</b></p> <ul style="list-style-type: none"> <li>• Aphids</li> <li>• Beet armyworm</li> <li>• Cabbage looper</li> <li>• Cutworms</li> <li>• Cyclamen mite</li> <li>• Spider mites</li> <li>• Whiteflies</li> </ul>	<p><b>Diseases</b></p> <ul style="list-style-type: none"> <li>• Angular leaf spot</li> <li>• Anthracnose</li> <li>• Botrytis fruit rot</li> <li>• Fusarium wilt</li> <li>• Macrophomina crown rot</li> <li>• Phytophthora crown and root rot</li> <li>• Powdery mildew</li> <li>• Red stele</li> <li>• Verticillium wilt</li> </ul>
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✓ Done	<h2>Pesticide application checklist</h2> <p>When planning for possible pesticide applications in an IPM program, review and complete this checklist to consider practices that minimize environmental and efficacy problems.</p>
	<p><b>✓ Choose a pesticide from the UC IPM Pest Management Guidelines for the target pest, considering:</b></p>
	<ul style="list-style-type: none"> <li>• Impact on natural enemies and pollinators.</li> </ul>
	<ul style="list-style-type: none"> <li>• Potential for water quality problems using the UC IPM WaterTox database. See <a href="http://ipm.ucanr.edu/TOX/simplewatertox.html">http://ipm.ucanr.edu/TOX/simplewatertox.html</a>.</li> </ul>
	<ul style="list-style-type: none"> <li>• Impact on aquatic invertebrates. For more information, see <i>Pesticide Choice</i>, UC ANR Publication 8161 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8161.pdf">http://anrcatalog.ucanr.edu/pdf/8161.pdf</a>.</li> </ul>
	<ul style="list-style-type: none"> <li>• Chemical mode of action, if pesticide resistance is an issue. For more information, see             <ul style="list-style-type: none"> <li>◦ <i>Herbicide Resistance: Definition and Management Strategies</i>, UC ANR Publication 8012 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8012.pdf">http://anrcatalog.ucanr.edu/pdf/8012.pdf</a>.</li> </ul> </li> </ul>

✓ Done	Pesticide application checklist
	<ul style="list-style-type: none"> <li>◦ Fungicide Resistance in Crop Pathogens: How Can It Be Managed? <a href="http://www.frac.info/docs/default-source/publications/monographs/monograph-1.pdf">http://www.frac.info/docs/default-source/publications/monographs/monograph-1.pdf</a>.</li> </ul>
	<ul style="list-style-type: none"> <li>• Endangered species that may be near your site. Find out using the Department of Pesticide Regulation's PRESCRIBE program. (<a href="http://www.cdpr.ca.gov/docs/endspec/prescint.htm">http://www.cdpr.ca.gov/docs/endspec/prescint.htm</a>)</li> </ul>
<b>✓ Before an application</b>	
	<ul style="list-style-type: none"> <li>• Ensure that spray equipment is properly calibrated to deliver the desired pesticide amount for optimal coverage. (See <a href="http://ipm.ucanr.edu/training/incorporating-calibration.html">http://ipm.ucanr.edu/training/incorporating-calibration.html</a>)</li> </ul>
	<ul style="list-style-type: none"> <li>• Use appropriate spray nozzles and pressure to minimize off-site movement of pesticides.</li> </ul>
	<ul style="list-style-type: none"> <li>• Avoid spraying during these conditions to avoid off-site movement of pesticides. <ul style="list-style-type: none"> <li>◦ Wind speed under 3 mph and over 10 mph</li> <li>◦ Temperature inversions</li> <li>◦ Just prior to rain or irrigation (unless it is an appropriate amount, such as when incorporating a soil-applied pesticide)</li> <li>◦ At tractor speeds over 2 mph</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>• Identify and take special care to protect sensitive areas (for example, waterways or riparian areas) surrounding your application site.</li> </ul>
	<ul style="list-style-type: none"> <li>• Review and follow labeling for pesticide handling, personal protection equipment (PPE) requirements, storage, and disposal guidelines.</li> </ul>
	<ul style="list-style-type: none"> <li>• Check and follow restricted entry intervals (REI) and preharvest intervals (PHI).</li> </ul>
<b>✓ After an application</b>	
	<ul style="list-style-type: none"> <li>• Record application date, pesticide used, rate, and location of application.</li> </ul>
	<ul style="list-style-type: none"> <li>• Follow up to confirm that treatment was effective.</li> </ul>
<b>✓ Consider water management practices that reduce pesticide movement off-site.</b>	
	<ul style="list-style-type: none"> <li>• Consult relevant publications: <i>Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops</i>, UC ANR Publication 8403 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8403.pdf">http://anrcatalog.ucanr.edu/pdf/8403.pdf</a>.</li> </ul>
	<ul style="list-style-type: none"> <li>• Consult the Department of Pesticide Regulation Groundwater Protection Program (GWPA) website for pesticide information and mitigation measures. (<a href="http://cdpr.ca.gov">http://cdpr.ca.gov</a>)</li> </ul>
	<ul style="list-style-type: none"> <li>• Install an irrigation recirculation or storage and reuse system. Redesign inlets into tailwater ditches to reduce erosion. For more information, see these publications: <ul style="list-style-type: none"> <li>◦ Reducing Runoff from Irrigated Lands: Tailwater Return Systems, UC ANR Publication 8225 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8225.pdf">http://anrcatalog.ucanr.edu/pdf/8225.pdf</a>.</li> <li>◦ Reducing Runoff from Irrigated Lands: Storing Runoff from Winter Rains, UC ANR Publication 8211 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8211.pdf">http://anrcatalog.ucanr.edu/pdf/8211.pdf</a>.</li> </ul> </li> </ul>
	<ul style="list-style-type: none"> <li>• Use drip rather than sprinkler or flood irrigation.</li> </ul>
	<ul style="list-style-type: none"> <li>• Limit irrigation to amount required using soil moisture monitoring and evapotranspiration (ET). (For more information, see <i>Reducing Runoff from Irrigated Lands: Understanding Your Orchard's Water Requirements</i>, UC ANR Publication 8212 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8212.pdf">http://anrcatalog.ucanr.edu/pdf/8212.pdf</a>.)</li> </ul>
	<ul style="list-style-type: none"> <li>• Consider using cover crops.</li> </ul>
	<ul style="list-style-type: none"> <li>• Consider vegetative filter strips or ditches. (For more information, see <i>Vegetative Filter Strips</i>, UC ANR Publication 8195 (PDF), <a href="http://anrcatalog.ucanr.edu/pdf/8195.pdf">http://anrcatalog.ucanr.edu/pdf/8195.pdf</a>.)</li> </ul>
	<ul style="list-style-type: none"> <li>• Use polyacrylamide (PAM) tablets in furrow irrigation systems to prevent off-site movement of sediments.</li> </ul>
<b>✓ Consider practices that reduce air quality problems.</b>	
	<ul style="list-style-type: none"> <li>• 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.</li> </ul>

For more about mitigating the effects of pesticides, see the Mitigation page: <http://ipm.ucanr.edu/mitigation/>.



## General Information

(Section reviewed 7/18)

# CHARACTERISTICS OF PUBLIC STRAWBERRY CULTIVARS COMMONLY GROWN IN CALIFORNIA (7/18)

Cultivar	Day length	Planting season	Region <sup>1</sup>	Supplemental storage <sup>2</sup>	Fruit characteristics	Plant characteristics	Susceptibility to pests and disorders <sup>3</sup>
<b>Albion</b>	neutral	fall	CC	10 to 18 days	large; excellent flavor; red internal and external color	moderately vigorous plant; high productivity, very long season; avoid overchilling, which causes excessive runner production	tolerant of <i>Verticillium</i> and <i>Phytophthora</i> ; moderately susceptible to powdery mildew
<b>Cabrillo</b>	neutral	fall	CC	10 to 21 days	good appearance, large, good flavor	vigorous, extremely high productivity	moderately susceptible to <i>Fusarium</i> and <i>Verticillium</i>
<b>Camarosa</b>	short	fall	CC, SC	none to 7 days	large; good flavor; excellent shelf life; good for fresh market and freezer pack; relatively resistant to rain damage	vigorous plant; high-yielding; early production; adapted to early fall planting	tendency to produce misshapen fruit; susceptible to <i>Verticillium</i>
<b>Camino Real</b>	short	fall	CC	7 to 14 days	large; very good flavor; highly tolerant of rain damage	not early; compact plant that needs adequate nursery chilling; good cultivar for Santa Maria Valley	sensitive to sulfur sprays; moderately tolerant to <i>Phytophthora</i> and highly tolerant to <i>Verticillium</i>
<b>Chandler</b>	short	summer	SJV	NA	medium size; very good flavor; somewhat tender skin; soft when temperatures are high	moderate yields	—
<b>Diamante</b>	neutral	fall	CC, SC	10 to 21 days	large; very good flavor; light color; sensitive to rain damage	moderately vigorous plant; high productivity; long season, open canopy, easy harvest	highly susceptible to <i>Phytophthora</i>
<b>Fronteras</b>	short	fall	CC, SC	3 to 7 days	very large fruit, good flavor, excellent fruit appearance	vigorous, very high yield	highly tolerant to <i>Fusarium</i> , <i>Macrophomina</i> and <i>Verticillium</i>
<b>Monterey</b>	neutral	fall	CC	3 to 14 days	large, good flavor	vigorous, high productivity	susceptible to powdery mildew, <i>Fusarium</i> and <i>Macrophomina</i> , moderately tolerant to <i>Verticillium</i>
<b>Portola</b>	neutral	fall/summer	CC, SC	7 to 14 days	large, fair flavor, lighter red color	vigorous, high productivity	tolerant to <i>Fusarium</i> , moderately tolerant to <i>Macrophomina</i> , highly susceptible to <i>Verticillium</i>
<b>San Andreas</b>	neutral	fall	CC	10 to 16 days	large, good flavor	vigorous, high productivity	tolerant to <i>Fusarium</i> and <i>Verticillium</i> and moderately tolerant to <i>Macrophomina</i>
<b>Ventana</b>	short	fall	CC, SC	none to 7 days	large; good flavor; good color but lighter than Camarosa; relatively resistant to rain damage	vigorous plant with heavy early production; adapted to early fall planting; good pollinator under adverse weather conditions; excellent for winter to spring fresh market	susceptible to <i>Phytophthora</i> ; fruit is susceptible to powdery mildew

— = Information not available    NA = not applicable

1 CC = Watsonville/Salinas and Santa Maria Valley

SC = South Coast region from San Diego to Ventura County

SJV = San Joaquin Valley

2 Approximate amount of chilling at 34° F (1° C) after fall digging needed for optimal vigor, yield, and fruit quality.

3 Tolerance or susceptibility is a measure of the impact of an infection on strawberry cultivar fitness; it is measured in terms of plant performance.

Acknowledgments: This table presents information on <http://research.ucdavis.edu/industry/ia/industry/strawberry/cultivars/> University of California cultivars. For privately-developed cultivars, information may be available from the company. Prepared with information from K.D. Larson, Dept. of Plant Sciences, UC Davis, South Coast Research & Extension Center, Irvine; D. V. Shaw, Dept. of Plant Sciences, UC Davis; M. P. Bolda, UC Cooperative Extension, Santa Cruz Co.; and O. Daugovich, UC Cooperative Extension, Ventura Co.

## DRIP FUMIGATION (7/18)

The most effective registered chemical alternative to methyl bromide plus chloropicrin fumigation for the control of pathogens, nematodes, and weed seeds is either

- chloropicrin mixed with 1,3-dichloropropene (InLine) followed by metam sodium *or*
- chloropicrin alone followed by metam sodium

Because chloropicrin and 1,3-dichloropropene are less volatile than methyl bromide, they can be applied to raised beds through drip irrigation systems and have been shown to be effective in controlling soilborne pathogens and most weed seeds, resulting in comparable strawberry yields. However, applying these materials through drip systems does not control the pathogens in the edges of raised beds.

Currently, over 55% of the California strawberry acreage is drip fumigated. Drip fumigation is convenient because workers are not required to be in the field during application. However, successful drip fumigation requires adequate soil preparation, a well-designed drip irrigation system, dependable chemigation equipment, well-laid plastic tarp, and timeliness of the process to accommodate longer plantback time.

### SOIL PREPARATION

As with all soil fumigation, the first step is to properly prepare and till the soil. Current soil preparation and bed listing practices used after methyl bromide fumigation are generally adequate. Following this, firmly pack the beds and eliminate any dirt clods. If the soil is dry, it may be necessary to preirrigate with enough water to initiate weed seed germination (1–1.5 acre-inch).

Uniform water distribution is necessary in a drip irrigation system and is easiest to obtain on fairly level terrain. On steep or hilly fields, create beds that follow soil contour lines at grades that do not exceed 4 feet uphill or 8 feet downhill from the beginning of the drip line.

When laying the plastic tarp, remove any shanks or chisels to avoid creating channels in the soil, which can result in poor water and fumigant distribution in the soil bed. Repair any holes or tears in the plastic tarp. Avoid embossed tarps to reduce loss of fumigants through volatilization. The use of totally impermeable film (TIF) will enhance weed control in the bed. However, TIF holds fumigants in the soil for longer periods than the standard tarp, so a longer plantback time or bed ventilation for 2 weeks before planting may be required (refer to the pesticide label).

### AMOUNT OF WATER

If chloropicrin or 1,3-dichloropropene is applied at the same time as metam sodium, they react and rapidly degrade in the irrigation water. Instead, they should be applied sequentially with the first application consisting of 1,3-dichloropropene plus chloropicrin or chloropicrin alone followed 5 to 7 days later with an application of metam sodium. Applying the pesticides in this order helps to maximize their effectiveness because 1,3-dichloropropene and chloropicrin are most effective in drier soils whereas metam works best in moist soils.

#### 1, 3-Dichloropropene and Chloropicrin

It is important to use the appropriate amount of water so that the fumigant is evenly distributed throughout the target soil treatment zone. Drip fumigation with recommended amounts of irrigation water will provide good fumigant distribution in soil and reduce fumigant volatilization losses by increasing the amount of fumigant in the water phase and decreasing the total air space available for fumigant diffusion in soil.

- If too little water is used (less than 1.5 inches), the fumigant will be poorly distributed and more likely to volatilize, resulting in less effective control and lower strawberry yields. In addition, with insufficient water and without an emulsifier, fumigants such as 1,3-D or chloropicrin may precipitate in the irrigation pipelines if the concentrations exceed their solubility limits of 2,000 parts per million (ppm).
- However, using too much water may lower the fumigant concentration in the main line below 500 ppm, which can reduce fumigant effectiveness. Also, beds can lose their integrity and become unstable and collapse with excessive water application. Thus, bed stability may limit the volume or application rate of water.

Table 1 (below) lists the recommended amount of water needed to fumigate various soil types to a 24-inch soil depth. For example

- In a sandy loam soil, 2 inches of water in the bed is recommended to fumigate 24 inches deep. With two drip tapes, this provides a 40-inch lateral spread (10 inches on each side of a drip tape).
- If irrigation duration is limited, cutting back to 1.75 inches on sandy loam soils is often acceptable because fumigants move 3 to 5 inches beyond the wetting front and control should extend 2 feet deep. Although the fumigant will volatilize and move beyond the wetted zone, the best treatment appears to occur within the wetted area.
- If the water volume is cut back to the minimum recommendation of 1.5 inches for sandy loam soils, the soil profile will be wetted 18 inches deep with 6 to 8 inches of horizontal spread on both sides of each drip tape.

### **Metam Sodium or Metam Potassium**

Metam sodium and metam potassium are water soluble and generate the active ingredient methyl isothiocyanate (MITC) after being applied to the soil. A minimum of one inch of water is recommended for the sequential application of metam to most soil types.

### **DRIP TAPE FLOW RATE AND SPACING**

In drip fumigation, the rate of water flow and the spacing of drip tapes are critical to the even distribution of the fumigant throughout the field as well as in the soil treatment zone. While a water distribution uniformity of 90% is possible in a well designed and operated drip system, at least 80% is necessary for acceptable fumigation.

Drip tapes with a flow rate between 0.3 to 0.7 gallons per minute (gpm) per 100 feet are appropriate for most strawberry soils in California (see Table 1 below). Low-flow drip tape requires longer application time that may become inconvenient. Avoid high-flow drip tape (greater than 0.7 gpm / 100 ft) if it causes any wetting of the furrows or runoff, or if it causes the beds to collapse. High-flow tape is not commonly used in California and is not recommended except for soils with high water permeability.

To achieve adequate water distribution uniformity, the pressure in the drip tape throughout the field should not vary more than 3 psi (e.g., from 6 to 9 psi). In addition, the system must be free of leaks and clogged emitters and be flushed and pressure tested before fumigation. It is imperative to use good quality irrigation components and drip tape. Leaks cause fumigant loss and possibly odor and emissions problems.

It may be necessary to reconfigure drip tape in order to obtain good water coverage across the soil bed. For most strawberry beds (sandy loam soils), one drip tape can cover up to 10 inches on each side. Therefore, two drip tapes are recommended for drip fumigation of most strawberry beds. In the two-row strawberry beds (narrow beds with two tapes near the center), spread the tapes as far apart as possible so that the edge of the bed is covered. In the four-row strawberry beds (wide beds with two tapes close to the shoulder), move the tapes a few inches towards the center to treat the middle of the bed. A third drip tape in the center may be needed if the bed top is wider than 40 inches. A third drip tape is also recommended in wide beds on sandy and loamy sand soils where limited lateral water movement may limit fumigant distribution.

**Table 1. Estimated water volume needed to treat two feet of soil depth using two drip tapes when applying 1, 3-dichloropropene or chloropicrin or both.<sup>1</sup>**

Soil type	Volume of application water inches per acre (gallons) <sup>2</sup>	Application time using 2 tapes (hours)				Comments
		Drip tape flow rate (gpm/100ft)				
		0.20	0.34	0.50	0.67	
Fine sand and loamy fine sand	1.6 (27,000)	13.9	8.2	5.5	4.1	Pre-irrigation with one inch of water is needed
Sandy loam and fine sandy loam	2.0 (34,000)	17.3	10.2	6.9	5.2	Minimum of 1.5 inches is recommended
Sandy clay loam and loam	2.6 (44,000)	22.5	13.4	9.0	NR	Split application may be required
Clay, clay loam, and silty clay loam	3.2 (54,000)	27.7	16.3	11.1	NR	Soils not common in strawberry production

<sup>1</sup> Application time and water volume based on 40-inch average bed width (64 inches center-to-center).

<sup>2</sup> One broadcast acre-inch of water is about 27,000 gallons. One acre-inch of water for a 40-inch wide bed is about 17,000 gallons.

NR = not recommended

## DETERMINING THE FUMIGANT CONCENTRATION IN IRRIGATION WATER

Fumigant concentration in the main line may vary from 500 to 1600 ppm, depending on soil type, fumigant, and water application rate. Below 500 ppm, the efficacy of chloropicrin plus 1,3-dichloropropene (InLine) to control soilborne pathogens may be insufficient. Also, because the solubility of chloropicrin and 1,3-D in water is less than 2000 ppm at 68°F (20°C), exceeding 1500 ppm may result in precipitation of these fumigants in the irrigation pipelines and drip tape.

Fumigant concentration in water can be calculated as follows:

- Chloropicrin: ppm chloropicrin = 119,826 × (# pounds chloropicrin / # gallons water)
- InLine: ppm (chloropicrin / 1,3-D) = 87,872 × (# pounds InLine / # gallons water)

Table 2 shows chloropicrin concentrations as a function of application rate and water volume. A similar table can be prepared for 1,3-dichloropropene plus chloropicrin (InLine) (one gallon weighs 11.2 lb or 6.81 lb 1,3-D and 3.73 lb chloropicrin) but is not provided here because 1,3-dichloropropene requires a special permit to apply.

## OTHER IMPORTANT CALCULATIONS NEEDED FOR DRIP FUMIGATION

- Determine the actual treated (bed) area, the total volume of water, and the weight of fumigants to be applied. Strawberry beds usually occupy 50 to 70% of the total area in the acre. Because only the beds are treated, this calculation can be important in determining how much fumigant is necessary for the treatment.
- Calculate the time required for application based on the flow rate of the drip tape.

Table 1 provides the application time for one particular type of bed configuration (40-inch wide with two drip tapes).

## CHEMIGATION EQUIPMENT FOR DRIP FUMIGATION

The fumigant cylinders are pressurized with nitrogen gas and metered directly into the irrigation pipeline or manifold. The meter can be a precision needle valve and flow meter, a needle valve and a scale, or a computer-controlled positive displacement meter. Fumigants are injected at low-flow rates and accurate calibration of injection equipment is essential for proper application. Fumigant concentration in the main line may vary from 500 to 1600 ppm, depending on the soil, fumigant type, and water application rate. Refer to the pesticide label for appropriate concentration rates.

Good fumigant mixing with water in the irrigation pipelines is essential. Install a static mixing device after the point of injection to thoroughly mix fumigants with water before being distributed into the irrigation system laterals and drip tape.

The irrigation system must have a standard, single-check valve, a low-pressure drain, and a vacuum-relief valve (a "chemigation" valve) upstream from the injection point to prevent possible contamination of the water source by fumigants. The fumigant injector must be equipped with a check valve to prevent water

from flowing back into the fumigant tank and an automatic quick-closing valve to stop fumigant injection when water flow is interrupted or loses pressure. The fumigant automatic shut-off valve can be electrically or hydraulically activated and should be normally closed at the injector. For more information on chemigation equipment, consult the agricultural commissioner office in your county.

### FLUSHING THE PIPELINE FOLLOWING TREATMENT

Many of the fumigants, including chloropicrin and 1,3-dichloropropene (InLine), can damage PVC if left in the pipelines. This does not occur during application of the diluted fumigants but can occur if the lines are not well flushed at the end of the application and the fumigant settles out and accumulates in low points of the distribution system. For this reason, it is critical to flush lines at the end of each application. The required amount of water needed to flush the system can be estimated as three times the volume of the mainline and laterals. Avoid excessive flushing because it will dilute the fumigants around the drip tape.

### SAFETY RULE

**Read and understand the fumigant label and follow county permit conditions before starting the fumigation.** Know the symptoms and emergency treatments for exposure to the fumigants. Monitor the application system and the field during application.

**Table 2. Chloropicrin concentration (ppm)<sup>1</sup> during drip application.**

Gallons water/acre	Pounds of chloropicrin (without emulsifier)															
	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
19,000	946	1,009	1,072	1,135	1,198	1,261	1,324	1,387	1,451	1,514	1,577					
20,000	899	959	1,019	1,078	1,138	1,198	1,258	1,318	1,378	1,438	1,498	1,558				
21,000	856	913	970	1,027	1,084	1,141	1,198	1,255	1,312	1,369	1,427	1,484	1,541			
22,000	817	871	926	980	1,035	1,089	1,144	1,198	1,253	1,307	1,362	1,416	1,471	1,525		
23,000	781	834	886	938	990	1,042	1,094	1,146	1,198	1,250	1,302	1,355	1,407	1,459	1,511	
24,000	749	799	849	899	949	999	1,048	1,098	1,148	1,198	1,248	1,298	1,348	1,398	1,448	1,498
25,000	719	767	815	863	911	959	1,007	1,054	1,102	1,150	1,198	1,246	1,294	1,342	1,390	1,438
26,000	691	737	783	830	876	922	968	1,014	1,060	1,106	1,152	1,198	1,244	1,290	1,337	1,383
27,000	666	710	754	799	843	888	932	976	1,021	1,065	1,110	1,154	1,198	1,243	1,287	1,331
28,000	642	685	728	770	813	856	899	941	984	1,027	1,070	1,113	1,155	1,198	1,241	1,284
29,000	620	661	702	744	785	826	868	909	950	992	1,033	1,074	1,116	1,157	1,198	1,240
30,000	599	639	679	719	759	799	839	879	919	959	999	1,038	1,078	1,118	1,158	1,198
31,000	580	618	657	696	734	773	812	850	889	928	966	1,005	1,044	1,082	1,121	1,160
32,000	562	599	637	674	711	749	786	824	861	899	936	974	1,011	1,048	1,086	1,123
33,000	545	581	617	654	690	726	763	799	835	871	908	944	980	1,017	1,053	1,089
34,000	529	564	599	634	670	705	740	775	811	846	881	916	952	987	1,022	1,057
35,000	514	548	582	616	650	685	719	753	787	822	856	890	924	959	993	1,027
36,000		533	566	599	632	666	699	732	766	799	832	865	899	932	965	999
37,000		518	551	583	615	648	680	712	745	777	810	842	874	907	939	972
38,000			536	568	599	631	662	694	725	757	788	820	851	883	914	946
39,000			522	553	584	614	645	676	707	737	768	799	830	860	891	922
40,000				539	569	599	629	659	689	719	749	779	809	839	869	899
41,000				526	555	585	614	643	672	701	731	760	789	818	848	887
42,000					542	571	599	628	656	685	713	742	770	799	827	856
43,000					529	557	585	613	641	669	697	725	752	780	808	836
44,000						545	572	599	626	654	681	708	735	763	790	817

<sup>1</sup> ppm = parts per million

# NON-FUMIGANT ALTERNATIVES FOR SOIL DISINFESTATION (7/18)

Due to increasing restrictions on fumigant use, considerable research efforts in the last decade have focused on developing non-fumigant alternatives to chemical fumigation of soil. These alternative technologies place greater emphasis on an integrated approach to soil pest and plant-soil environment management compared to standard broadcast soil fumigation. The target of the alternative approaches is to sustain cost-effective fruit production systems without chemical fumigation, including organic production. The strategies combine the use of resistant cultivars and site-specific management with soil treatments such as soil solarization, steam application, anaerobic soil disinfestation (ASD), soil substitution with soilless media, and use of naturally produced biocides.

## CULTIVAR SELECTION

Using cultivars most fitted for production conditions and the soil pathogens present in the field is of great importance in fumigated soil and is absolutely critical in non-fumigated soils. The table CHARACTERISTICS OF PUBLIC STRAWBERRY CULTIVARS COMMONLY GROWN IN CALIFORNIA shows susceptibilities of current cultivars to key pathogens and their production characteristics. Breeding for soilborne disease resistance has become one of the primary objectives for the development of new cultivars due to methyl bromide's replacement with less effective fumigants and the greater focus on non-fumigant alternatives.

## SOIL SOLARIZATION

In summer, clear plastic applied to preshaped beds several weeks before planting will solarize the soil and reduce the number of soilborne disease organisms and weed seeds (by making them inviable). On the central coast, this practice requires at least 12 to 15 weeks in order to obtain pest management benefits; consequently, solarization is usually not practical in this region. Solarization is much more effective in areas of the state where temperatures are consistently (30–45 days) hot enough in summer to produce soil temperatures of at least 122°F. Solarization can be even more effective if the residue of a cruciferous crop (especially broccoli or mustards) is incorporated into the soil just before the plastic is installed or following an application of metam sodium. For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377. For optimum results, check the plastic for good adhesion to the soil and for any holes that might have developed and need repair.

## STEAM APPLICATION

Steam kills weed seed and soil pathogens by transferring heat from a steam boiler to soil particles and soil pests. Sufficient steam must be applied to maintain a temperature of approximately 160°F for a duration (dwell time) of 20 minutes. Steam application to soil has a similar effect to soil solarization, although the length of time for treatment is much less for steam. Adoption of steam disinfestation of field soils has been hindered by high fuel consumption, labor, and application time required. Steam provides effective control of weeds and pathogens and yields similar to fumigated strawberries.

Applications of steam that applied  $1.55 \times 10^5$  British thermal units (BTU) per cubic meter of heat raised the soil temperature to 160°F for 20 minutes. This results in control of annual bluegrass (*Poa annua*), common chickweed (*Stellaria media*), burning nettle (*Urtica urens*), and common purslane (*Portulaca oleracea*), as well as yellow nutsedge tubers (*Cyperus esculentus*). Application of steam to soil has also been shown to control sowthistle (*Sonchus oleraceus*), burclover (*Medicago polymorpha*), purple cudweed (*Gnaphalium purpureum*), lesser swinecress (*Coronopus didymus*), vetch (*Vicia* spp.), corn spurry (*Spergula arvensis*), and little mallow (*Malva parviflora*). Steam achieves greater than 90% control of these weeds, which is approximately the same as field fumigation with chloropicrin/1,3-dichloropropene.

Traditional sheet steam applications in greenhouses and fields use heavy tarps to cover soil while steam is injected under the tarp. It generally takes 8 hours to treat fractions of an acre. Mobile steam applicators are currently under development.

For more information on traditional sheet steam applications, see *The UC System for Producing Healthy Container-Grown Plants*. For information on mobile steam applicators, see *Evaluation of a Mobile Steam Applicator for Soil Disinfestation in California Strawberry*.

## ANAEROBIC SOIL DISINFESTATION (ASD)

Anaerobic soil disinfestation is a method of treating soil that utilizes a carbon source and moisture to produce anaerobic soil conditions over several weeks. These conditions change soil properties, making the soil environment less favorable for certain soilborne pathogens, thus providing some reduction in soilborne disease. This is a relatively new technique with benefits and limitations that are not well understood.

The standard anaerobic soil disinfestation treatment involves

- uniform mixing of easily biodegradable carbon source (e.g., rice bran) into the top 24 inches of soil just before strawberry beds are listed,
- covering the new beds with plastic mulch,
- applying irrigation (if needed), and
- maintaining anaerobic conditions for 3 to 5 weeks.

Tears and holes in plastic will allow aeration and should be avoided or patched during the anaerobic process. One to two days before planting, holes can be cut to allow aeration. Then, planting can begin immediately.

Processes and changes that take place during and after anaerobic soil disinfestation application period that likely benefit the soil environment for plant growth include

- anaerobiosis,
- production of organic acids and volatiles,
- lowering of pH,
- increase in available nitrogen and phosphorus, and
- changes in physical and microbiological properties of soil.

Rice bran (at 9 tons/acre) has been the most common carbon source for anaerobic soil disinfestation with annual application to more than 1,000 acres in California, mostly in organic fields. Rice bran-based anaerobic soil disinfestation provides consistent improvements in plant productivity compared to non-treated soil and fruit yields similar to those obtained in fumigated soil. Anaerobic soil disinfestation shows good efficacy in reducing Verticillium wilt (caused by *V. dahliae*) levels in soil and provides significant control of many broadleaf annual weeds in Southern California. However, current anaerobic soil disinfestation technology does not control important strawberry pathogens like *Fusarium oxysporum* and *Macrophomina phaseolina* or perennial weeds.

## SOILLESS MEDIA

Culture in soilless media (sterile substrates) is a very intensive system but nevertheless offers an alternative to farming in soil for high value crops such as tomatoes, peppers, and strawberries.

The advantages of the soilless system are clear: more control over the rooting medium, a theoretically pathogen free environment, and absolute control over irrigation and fertility. Gravel, sand, and rock wool have been used previously as substrates. Current research is evaluating organic substrates such as coconut coir and peat moss as a substrate for their superior nutrient and moisture holding capacity, aeration, leaching, and reusability. The substrate system also offers benefits to labor when beds are raised to waist or eye level, which prevents stooping and increases productivity, especially in older workers.

Soilless culture is almost always performed in greenhouses or high plastic tunnels (i.e., “hoops”), and planting configurations can vary widely. In greenhouses, strawberries can be planted in stepped, rotating, or fixed troughs, stacked in perforated cylinders, or built up in pyramids. The goal of these configurations is to achieve maximum exposure to sunlight. In the field, recent research on a raised-bed soilless media system shows significantly higher production costs compared to standard field soil production but no significant fruit yield improvements.

The holding pot of the substrate plant must be given careful consideration. Colors should be light so as to not accumulate heat too quickly, and it is highly recommended to use interlocking troughs of shorter length, which prevents transmission of any root pathogen over long stretches of planting medium.

Irrigation and fertility of strawberries grown in soilless media is the key to successful production. Watering must be frequent, and salinity must be monitored at all times to ensure that it does not reach harmful levels. Since managers of strawberries in soilless culture are injecting fertilizers and potential salts with the water into the substrate, it is very easy to exceed safe levels of electrical conductivity (EC) very quickly.



For more information on soilless substrate, see Technical Equipment in Soilless Production Systems.

## **NATURALLY PRODUCED BIOCIDES**

Biocides are naturally produced pesticides that are most commonly comprised of seed meal or the aboveground biomass of high-glucosinolate plants from the *Brassicaceae* family (mustards). The breakdown of glucosinolate yields several biologically active compounds such as low levels of isothiocyanates, the active ingredients in fumigants such as metam sodium, potassium, and allyl-isothiocyanate.

These pesticides have not been observed to consistently control soilborne pathogens. Although on-site cover cropping with mustards and the use of seed meal have reduced numbers of weeds and nematodes at some sites, the time or cost needed to produce sufficient cover crop biomass or apply seed meal has been prohibitive for widespread application. Additionally, seed meal may be phytotoxic to strawberry if applied at high rates close to transplanting.

Even though biocides have limited uses for pest management, it is worth noting their potential benefits to strawberry production due to contribution of nitrogen and organic matter. In addition, mustard is a strong competitor with weeds when grown as a cover crop. When considering cover crop selection, consult with the UC Cover Crop Guide.

For current information about non-fumigant technologies in your production area, contact your local UCCE advisor or specialist.

## FIELD SELECTION (7/18)

To reduce management costs, select fields with desirable characteristics and a minimum of potential pest problems.

- Deep, well-drained, sandy loam soils are preferred for strawberry production because field preparation is easier, fumigation is more effective, accumulation of salts is less, drainage is better, and the soil is better suited to the frequent irrigation and field activity that strawberries require. Avoid poorly drained soils to minimize problems with root diseases such as *Phytophthora* root and crown rot.
- Choose fields that are easy to grade to the proper slope and have good air drainage so cold air doesn't settle in the field.
- Ensure an adequate supply of good-quality water. Make sure that soil and field conditions allow you to maximize use of available water to grow strawberries.

## CROPPING HISTORY

An accurate field history will help you evaluate the effectiveness of management actions and make long-term planning easier. (It may be useful to organize information in a spreadsheet, combining all data from a given field for several years in a single document.) For each field, keep records of:

- Routine field surveys, including dates and GPS locations;
- Weed surveys;
- Results of laboratory analyses such as soil tests, water tests, and pest identifications;
- Horticultural information, including cultivars, planting dates, source of transplants, harvest dates, and yields;
- Dates of pesticide applications, including pesticide names and rates, and their effectiveness.

## CHECK POTENTIAL PROBLEMS BEFORE PLANTING

Before you begin preparing your fields for planting, a number of monitoring activities are important in helping you plan your pest management program for the season.

- Consult field records for cropping history, cultural practices, pesticide use, and problems with pests, soil conditions, and salinity. Check plantback restrictions to be sure herbicides with long residual life were not used on the previous crop.
- Survey the field for weeds and record your results (example form). Avoid planting strawberries if infestations of field bindweed or yellow nutsedge or high densities of little mallow or burclover are present.
- Collect samples of irrigation water and field soil for analysis of salinity, nutrient levels, and microbial contaminants.
  - Have the soil and water tested for salts and salinity. If the water supply has more than 900 to 1000 ppm total salts, special precautions will be needed to avoid injurious salt buildup. If salt levels are too high, you may want to avoid planting strawberries or else plan extra irrigations to rinse excess salts away from the strawberry root zone. Irrigations to reduce soil salinity are best done before preparing fields for fumigation and planting and can take years to improve conditions measurably.
  - Have the soil tested for boron and zinc to assure optimum levels.
- Survey adjacent areas for pests that may move into strawberries: for example, infestations of twospotted spider mites, whiteflies, cutworms, or armyworms; weed hosts of lygus bugs; potential sources of root weevils; weeds with wind-dispersed seed; signs of vertebrate pests such as ground squirrels, gophers, voles, or moles.
- If possible, visit nurseries where you plan to get your transplants to learn about their pest control programs and management practices.

## CROP ROTATION

Rotating strawberries with a cover crop such as rye, barley, or a mix of barley and bell beans may enhance pest control and help improve soil structure. A heavy stand of cereal rye or barley provides additional weed control because these crops are very competitive with weeds and allow broadleaf herbicides to be used to control weeds that can be serious problems in strawberries. In addition, rye does not host some of the pests that attack strawberries and can help reduce root-knot nematodes and soil levels of *Verticillium*, although significant disease control requires long-term rotations.

Mustards generally are the best weed competitors among commonly used cover crops, and their residue breaks down faster compared to cereals. Additionally, mulched mustard residue might reduce viability of *Phytophthora* in the soil.

Rotation with vegetable crops may allow additional weed control options and provide economic returns. Incorporation of broccoli residues may reduce population levels of soil pathogens including *Verticillium*. Winter vegetable operations can result in soil compaction and deterioration of soil structure. Incorporation of cover crop residue loosens the soil and can help improve soil drainage. Be sure to allow enough time for the cover crop to decompose before preparing the field for strawberry planting.

Long-term use of soil amendments can improve soil structure and drainage.

## FIELD PREPARATION (7/18)

Careful preparation of your fields for preplant treatments and planting can make pest management easier. Important considerations include soil type, crop residue, bed design, proper drainage, and whether you plan to fumigate the soil before or after beds are formed.

- Do not work the field when the soil is wet or when it is very dry because the soil structure will be damaged. Prepare beds with proper slope (at least 0.75%) so that water does not stand in the field and drains off during rainy weather without causing soil erosion. Shape beds properly so that water drains away from the tops of the beds. On hillsides, form beds on a contour to minimize soil erosion.
- Prepare fields far enough in advance of fumigation that residue from the previous crop will be decomposed. Pathogens present in crop residue may not be killed by fumigation. Work reasonably dry soil until it is free of clods; fumigants do not penetrate clods, and working wet soil causes compaction that interferes with successful fumigation. It may be necessary to sprinkle-irrigate dry soil before fumigating because fumigation is less effective in dry soils. These guidelines also apply if you are planning to use soil solarization or drip fumigation.
- If sulfur or gypsum is needed, apply it several months before planting and thoroughly mix it with the soil. Rain or irrigations will then leach excess salts from the root zone. If gypsum is being used to improve water infiltration, apply it to the soil surface without mixing it into the soil.

### DRAINAGE

Good drainage is essential to keep salts from building up in the root zone and reduce root disease problems. Always rip the subsoil several times to provide adequate drainage. Perched water tables, compacted soil layers, and stratified or layered soils must be corrected during field preparation. Deep subsoiling or chiseling to a depth of 30 inches may remove these obstructions and should be repeated every year.

In some cases, organic amendments can improve drainage. Be careful to choose amendments that do not contribute to salt problems. If using manures or composts, mix them into the soil far enough in advance that rains or irrigations will ensure that excess salts are rinsed from the root zone before planting.

High beds improve drainage, so increasing bed height may help alleviate drainage problems. Be sure to provide for adequate drainage from the field during rainy weather; standing water favors the development of root and crown diseases. Drip-irrigated fields should have a uniform slope of 0.75 to 1%. Ideally, water from rains should not be allowed to stand in strawberry fields for more than about 6 hours.

### FORMING BEDS

Planting beds may be formed before or after soil fumigation. If you are planning to use solarization for weed control, you must form the beds first. Two-row or four-row beds may be used. Four-row beds are most common in the Santa Maria Valley and Southern California areas, while two-row beds are most common in the Watsonville-Salinas area. Salinity management, pest control, and harvest may be more difficult with four row beds.

When setting up planting beds in hilly areas, plan to leave natural draws free of plants—for example, by making roadways between planting blocks. This will allow cold air drainage and help reduce the risk of low temperature injury.

### POLYETHYLENE MULCH

Covering the planting bed with polyethylene mulch helps regulate soil temperature, which in turn helps regulate plant growth and fruit production. Mulching also conserves soil moisture and reduces salinity build up on the soil surface and is very important in reducing decay problems by limiting fruit contact with soil and irrigation water.

Preplant weed control is critical, unless opaque mulch is used, because clear and translucent mulches do not control weed growth. The type of mulch used and the timing of application depend on cultivar, planting and harvest seasons, and other management practices.

Polyethylene mulch may be applied by machine before planting or by hand or machine after plants are in place. When applied after planting, the plastic is unrolled lengthwise over the bed and secured to the bed shoulders with metal pins placed every 6 to 8 feet or with a layer of soil turned over the edge of the mulch. Either rotating

drums with tines that slice the plastic are used to create a hole for the plant or a special burner is used to heat a metal cylinder that punches a hole in the plastic over each plant and the plants are pulled through the holes. An advantage of the tines is that they create a smaller hole and there is less weed growth, but the larger holes created by the burners allow more water to get to the plant if overhead irrigation is used. If bed fumigation is used, mulch is applied before planting. Plastic bags filled with soil are placed as needed to keep wind from damaging the mulch.

### **Clear Polyethylene**

Clear mulch allows sunlight to heat the soil during short winter days, stimulating crown development and thereby enhancing early and total yield.

#### *Santa Maria Valley and Southern California*

Apply clear polyethylene to fall-planted strawberries before or as soon as possible after planting. Clear mulch with opaque sides that covers the bed shoulder is also used in Southern California. It provides the advantage of warming soil on the bed top while controlling weeds on the sides of beds, where drip-applied fumigant concentrations are often insufficient for optimal weed control.

#### *Watsonville-Salinas area*

Short-day cultivars may be planted through clear mulch or clear mulch applied soon after planting to encourage winter growth. For day-neutral cultivars, clear mulch is usually applied in mid- or late December.

#### *Central Valley areas*

Clear polyethylene may also be used when summer plantings are planted later than recommended; it is important to apply the clear mulch in early November to stimulate crown growth during late fall and winter. Applying clear mulch in late December or January when day length is increasing stimulates runner growth and shortens the fruit production season.

### **White Polyethylene**

White or white-on-black mulch cools the soil significantly, slowing early growth, and favoring production of larger fruit and prolonging the fruit production season of some cultivars. In the Central Valley, apply white polyethylene to summer plantings immediately after pruning. White mulch is least likely to burn fruit during hot weather. Most white mulch is translucent and does not inhibit weed growth. White mulch with black backing does control weed growth. Reflection from white and silver-colored mulches helps repel some insect pests such as greenhouse whitefly.

### **Opaque Polyethylene**

Opaque polyethylene, such as those colored black, brown, or green, provides considerable soil warming (but less than clear) and controls weed growth on the planting bed. However, shoots of yellow nutsedge can puncture holes and grow through opaque mulch. Black mulch can lead to problems with fruit burn when temperatures are high (above 90°F).

# HANDLING STRAWBERRY TRANSPLANTS (7/18)

## CERTIFIED TRANSPLANTS

Several different strawberry pathogens can be transmitted from the nursery to fruiting fields in infected transplants. These include viruses, phytoplasmas, foliar and root-knot nematodes, and various fungi that cause plant diseases. In addition, weed seeds and vegetative reproductive structures of perennial weeds can be spread on contaminated transplants.

Use certified transplants to prevent virus diseases and foliar nematode in fruit production fields. Certified transplants also play an important role in reducing the spread of other strawberry pathogens into fruit production fields and help reduce spread of weed problems because certified fields generally are kept weed free.

One source of virus-tested plants for propagation by nurseries is the Strawberry Program of the University of California's Foundation Plant Services (FPS). At FPS, plants to be propagated by nurseries are tested to ensure that they are free of the virus diseases considered important in California strawberry production. Buyers of these virus-indexed plants from FPS must be licensed with UC Davis InnovationAccess as a propagator of university-patented strawberry material. Royalties are collected by UC upon the sale of nursery stock. More information can be obtained by contacting the Strawberry Licensing Program

Mother plants are tested for these pathogens by the Strawberry Program of University of California's Foundation Plant Services:

Pathogen	Detection methods <sup>1</sup>
<i>Arabid mosaic virus</i>	HI
<i>Raspberry ringspot virus</i>	HI
<i>Strawberry crinkle virus</i>	SI, PCR
<i>Strawberry feather leaf virus</i>	SI
<i>Strawberry latent C virus</i>	SI
<i>Strawberry latent ringspot virus</i>	HI, PCR
<i>Strawberry leaf roll disease</i>	SI
<i>Strawberry mild yellow edge virus</i>	SI, PCR
<i>Strawberry mottle virus</i>	SI, PCR
<i>Strawberry pallidosis associated virus</i>	SI, PCR
<i>Strawberry vein banding virus</i>	HI, PCR
<i>Tobacco necrosis virus</i>	HI
<i>Tobacco ringspot virus</i>	HI
<i>Tobacco streak virus= strawberry necrotic shock virus</i>	SI, PCR
<i>Tomato black ring virus</i>	HI
<i>Tomato bushy stunt virus</i>	HI
<i>Tomato ringspot virus</i>	HI
<i>Xanthomonas fragariae (angular leafspot)</i>	PCR
<i>Phytophthora fragariae var. fragariae (Red steel root rot)</i>	VI
<i>Aphelenchoides besseyi (Strawberry crimp nematode)</i>	VI
Phytoplasmas	PCR

<sup>1</sup> SI = strawberry indicator plants; PCR = polymerase chain reaction; HI = herbaceous indicator plants; VI = visual inspection

Once plants reach the nursery stage, the California Department of Food and Agriculture administers a Strawberry Certification Program of virus testing and nursery inspections designed to ensure that certified transplants are as free as possible from potentially harmful pathogens and weeds. All strawberry plants that receive certification tags must meet the requirements of this program.

The first nursery generation of certified strawberry plants is produced by allowing virus-tested meristem plants to multiply in screenhouses, where they are protected from virus vectors. The certification program tests one daughter plant from each meristem plant for the viruses mentioned above.

Next, three or more generations may be produced in the field. The packaged plants of each generation that passes certification inspection receive a tag of a different color.

- The first generation is called Foundation and receives a white tag,
- The second generation is called Registered and receives a purple tag, and
- The third is called Certified and receives a blue tag.
- Subsequent generations are noncertified and receive no tag.

Soil fumigation is supervised by the county agricultural commissioner and fields are inspected at planting, during the season, at harvest, and during trimming and packing operations for signs of pests. Inspectors look for diseases, insects, weeds, nematodes, correct number of plants per package, and off-type plants. Plants representing at least 1% of all plants in each foundation block clone are tested for viruses using the leaf grafting technique.

Certified transplants or plants of an equivalent generation usually are used for fruit production, but the more expensive Registered plants may also be used if an additional level of cleanliness is desired.

## PLANTING

To achieve optimum plant vigor, it is essential to follow recommended procedures for handling and planting the cultivars. Good plant vigor increases yields and reduces the impact of pests.

### Planting Dates

The best time to plant depends on cultivar and location. Yield, quality, and earliness of production are affected by planting date. The correct planting date helps ensure vigorous growth, improves yields, and reduces pest problems. Planting too early reduces vigor and yield, may increase mite problems, and may result in a higher incidence of misshapen, small fruit. Planting too late causes excessive growth of foliage and runners, delays fruit production, and decreases yield.

- Summer planting is used in the Central Valley.
- Planting in spring and summer (both usually called "summer" plantings) is used for fall-harvest, day-neutral cultivars in the Santa Maria Valley and Southern California areas.
- Fall planting (sometimes called "winter" planting) is used in all areas except the Central Valley and is the most widely used planting timing in the state. (Successful fall planting requires mild autumn weather that allows crown production during the shortest days of the year.)

### Handling Transplants

Keep transplants protected during planting operations to prevent drying, and place them into beds with soil moisture near field capacity. In fields fumigated before beds are formed, transplants usually are placed into holes punched into the tops of formed beds by machine either before or after polyethylene mulch has been applied.

Proper placement of transplants is critical. For this reason, all transplants are planted by hand. Make sure that the crown is properly exposed after the soil is closed around the transplants. Plants die if placed too deep and grow poorly if placed too shallow. Roots should be vertical in the planting slot and not be allowed to form a 'J'. If excessive root length interferes with proper planting, roots may be pruned but should never be less than 4 inches in length. Place transplants no farther than 6 to 7 inches from a drip line.

Recommended planting densities vary with cultivar, nursery source and planting date, nitrogen fertilizer management, soil type, field location, and bed width. In all plantings, plants are staggered, placing them as far apart from each other as practical on the bed. This practice minimizes plant competition and improves spray

coverage. Planting too closely reduces fruit size, makes picking inefficient, and increases problems with diseases, especially gray mold, and uneven coloring. Planting too far apart reduces yields unnecessarily.

- In 4-row beds of the Santa Maria Valley and Southern California, planting densities vary from 22,000 to 28,000 plants per acre, with the most common plant spacings using about 24,000 plants per acre.
- Planting densities for 2-row beds in the Watsonville and Salinas area vary between 16,000 and 20,000 plants per acre.
- Higher plant densities are designed to give higher yields early, while lower plant densities are designed for a longer season where plant crowding is minimized later in the growing season.

## PLANT ESTABLISHMENT

Sprinkler irrigation immediately after planting is the best way to establish transplants. Newly developing roots need good soil-root contact with adequate moisture and are sensitive to dryness and salinity. Careful placement of fertilizer and frequent irrigation is needed to prevent reductions in growth and yield. Frequent irrigation is critical during the first 4 weeks after planting. Irrigate often enough to keep soil in the beds near field capacity (tensiometer readings of 5 to 10 centibars) but avoid standing water. Excessive irrigation encourages diseases. If drip irrigation is used to get plants established, place the drip lines and mulch, then irrigate long enough to bring beds to field capacity before planting. Winter irrigation may be needed if the soil dries out.

Occasionally, strawberry plants form runners in fall after planting. Runners must be removed to encourage the formation of large, high-yielding plants. Remove runners as soon as enough are present to justify sending crews through the field. Runner removal may be combined with hand-weeding operations. Cultivars differ widely in their production of runners and this should be considered for cultivar selection alongside chilling requirements.



## RELATIVE TOXICITIES OF INSECTICIDES AND MITICIDES USED IN STRAWBERRY TO NATURAL ENEMIES AND HONEY BEES (7/18)

Common name (Example trade name)	Mode of action <sup>1</sup>	Selectivity <sup>2</sup> (affected groups)	Predatory mites <sup>3</sup>	General predators <sup>4</sup>	Parasites <sup>4</sup>	Honey bees <sup>5</sup>	Duration of impact to natural enemies <sup>6</sup>
abamectin (Agri-Mek)	6	moderate (leafminers, mites)	M	L	M/H	I	long to predatory mites and affected insects
acequinocyl (Kanemite)	20B	narrow (mites)	— <sup>7</sup>	—	—	III	—
acetamiprid (Assail)	4A	moderate (sucking insects)	— <sup>8</sup>	— <sup>7</sup>	—	II	moderate
azadirachtin (AzaGuard, Neemix)	un	broad (insects, mites)	M	L/M	L/M	II	short
<i>Bacillus thuringiensis</i> ssp. <i>aizawai</i> (Agree, Xentari)	11A	narrow (caterpillars)	L/M	L/M	L	II	short
<i>Bacillus thuringiensis</i> ssp. <i>kurstaki</i> (Deliver, Dipel)	11A	narrow (caterpillars)	L	L	L	III	short
<i>Beauveria bassiana</i> (BotaniGard)	—	broad (insects, mites)	—	—	—	II	—
bifenazate (Acrامة)	20D	narrow (spider mites)	L	L	L	II	short
bifenthrin (Brigade)	3A	broad (insects, mites)	H	H	H	I	long
<i>Burkholderia rinojensis</i> (Venerate)	—	broad (insects, mites)	—	—	—	—	—
carbaryl, bait (Sevin Bait)	1A	narrow (armyworms, cutworms, grasshoppers)	L	L	L	I	short
chlorantraniliprole (Coragen)	28	narrow (primarily caterpillars)	L	L	L/M	III	short
<i>Chromobacterium subsugae</i> (Grandevo)	—	broad (insects, mites)	—	—	—	—	—
diazinon	1B	broad (insects, mites)	L	H	H	I	moderate to long
etoxazole (Zeal)	10B	narrow (mites)	H <sup>7</sup>	L	—	II	short
fenbutatin oxide (Vendex)	12B	narrow (pest mites)	L	L	L	III	short
fenpropathrin (Danitol)	3A	broad (insects, mites)	H	H	H	I	—
fenpyroximate (FujiMite 5SC)	21A	narrow (mites, some insects)	H	L	L	III	short
hexythiazox (Savey)	10A	narrow (mites)	M	L	L	II	short to moderate
imidacloprid (Admire)	4A	narrow (beet armyworm, cutworms, sucking insects)	—	L	—	I	—
insecticidal soap (M-Pede)	—	broad (exposed insects, mites)	L	L	L	III	short
<i>Isaria fumosorosea</i> (Pfr-97)	—	broad (insects, mites)	—	—	—	—	short
malathion	1B	broad (insects, mites)	M	H	H	I	moderate
<i>Metarhizium brunneum</i> (Met52)	—	broad (insects, mites)	—	—	—	—	—
methomyl (Lannate)	1A	broad (insects, mites)	H	H	H	I	moderate
methoxyfenozide (Intrepid)	18	narrow (caterpillars)	L	L	L	II	short
naled (Dibrom)	1B	broad (insects, mites)	H	H	H	I	—
neem oil (Trilogy)	—	broad (soft-bodied insects, mites)	L	L	L	II	shorts
novaluron (Rimon)	15	narrow (insects)	L	L/M	—	—	short to moderate
paraffinic oil (JMS Stylet Oil)	—	broad (exposed insects, mites)	L	L	L	II	short
petroleum oil	—	broad (exposed insects, mites)	L <sup>9</sup>	L	L	II	short
pyrethrins (PyGanic)	3A	broad (insects)	—	M	M	I	short
pyrethrin/piperonyl butoxide (Pyrenone)	3A/—	broad (insects)	—	—	—	I	short to moderate
pyriproxyfen (Esteem)	7C	narrow (whiteflies)	L	H <sup>10</sup>	L	II	long

Common name (Example trade name)	Mode of action <sup>1</sup>	Selectivity <sup>2</sup> (affected groups)	Predatory mites <sup>3</sup>	General predators <sup>4</sup>	Parasites <sup>4</sup>	Honey bees <sup>5</sup>	Duration of impact to natural enemies <sup>6</sup>
rosemary oil (Hexacide)	—	broad (exposed insects, mites)	L	L	L	III	—
spinetoram (Radiant)	5	narrow (caterpillars, fruit flies, leafminers, thrips, whiteflies)	M	M <sup>11</sup>	L/M	II	moderate <sup>12</sup>
spinosad (Entrust, Success)	5	narrow (caterpillars, fruit flies, leafminers, thrips, whiteflies)	M	M <sup>11</sup>	L/M	II	short to moderate <sup>11</sup>
spiromesifen (Oberon SC)	23	narrow (mites, whiteflies)	—	—	—	II	—
thiamethoxam (Actara)	4A	narrow (sucking insects)	— <sup>8</sup>	—	M	I	moderate

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

- 1 Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://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 generally to *Phytoseiulus persimilis*.
- 4 Toxicities are averages of reported effects and should be used only as a general guide. Actual toxicity of a specific insecticide depends on factors including the application rate, environmental conditions, and life stage and species of parasite or predator.
- 5 Ratings are as follows: I-Do not apply or allow to drift to plants that are flowering; II-Do not apply or allow to drift to plants that are flowering, except when the application is made between sunset and midnight if allowed by the label and regulations; III-No bee precaution, except when required by the label or regulations. For more information about pesticide synergistic effects, see *Bee Precaution Pesticide Ratings*.
- 6 Duration: *Short* means hours to days; *moderate* means days to two weeks; and *long* means many weeks or months.
- 7 Acute toxicity low but reproductive capacity is reduced.
- 8 May cause an increase in spider mites.
- 9 Use lowest rates for best management of predatory mite to spider mite ratio.
- 10 Kills lady beetles.
- 11 Toxic to some natural enemies (lacewing and syrphid fly larvae, predatory beetles and thrips) when sprayed and up to 5 to 7 days after, especially for syrphid fly larvae.
- 12 Residual is moderate if solution is between pH of 7 to 8.

Acknowledgments: 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 STRAWBERRIES (7/18)

Common name (Example trade name)	Class	Group (FRAC) number <sup>1</sup>	Activity	Mode of action	Resistance potential	Comments
azoxystrobin (Abound, Quadris Top)	QoI <sup>4</sup>	11	contact, systemic <sup>2</sup>	single-site	high	Resistance in <i>Botrytis</i> and <i>Colletotrichum</i> documented
captan	phthalamide	M4	contact	multi-site	low	toxic to honey bee larvae
chlorothalonil (Bravo)	chloronitrile	M5	contact	multi-site	low	
cyflufenamid (Torino)	phenyl-acetamide	U6	contact	—	—	
cyprodinil/fludioxonil (Switch)	anilinopyrimidine /phenylpyrrole	9/12	contact/slightly systemic	single-site/single-site	medium	
fenhexamid (Elevate)	hydroxylanilide	17	contact	single-site	medium	Resistance in <i>Botrytis</i> documented
fluopyram (Luna Privilege)	SDHI <sup>5</sup>	7	contact	single-site	high	
fluopyram/trifloxystrobin (Luna Sensation)	SDHI <sup>5</sup> /QoI <sup>4</sup>	7/11	contact, systemic	single-site/single-site	high	
fosetyl-al (Aliette)	phosphonates	33	systemic	unknown	low	
insecticidal soap (M-pede)	inorganic salt	—	contact	—	low	
iprodione (Rovral)	dicarboximide	2	systemic (local)	single-site?	high	toxic to honey bee larvae
isofetamid (Kenja)	SDHI <sup>5</sup>	7	contact	single-site	high	
mefenoxam (Ridomil Gold)	phenylamide	4	contact, systemic	single-site	high	
myclobutanil (Rally)	DMI <sup>3</sup>	3	systemic (local) <sup>2</sup>	single-site	medium	
penthiopyrad (Fontelis)	SDHI <sup>5</sup>	7	contact	single-site	high	
phosphorous acid (Fosphite)	phosphonates	33	systemic	multi-site?	low	
pyraclostrobin/boscalid (Pristine)	QoI <sup>4</sup> /SDHI <sup>5</sup>	11/7	contact, systemic <sup>2</sup>	single-site/single-site	high	Resistance in <i>Botrytis</i> documented
pyraclostrobin/fluxapyroxad (Merivon)	QoI <sup>4</sup> /SDHI <sup>5</sup>	11/7	contact, systemic	single-site/single-site	high	
quinoxifen (Quintec)	azanaphthalenes	13	contact	single-site	medium	
sulfur	inorganic	M2	contact	multi-site	low	
tetraconazole (Mettle)	DMI <sup>3</sup>	3	systemic (local)	single-site	high	
thiophanate-methyl (Topsin-M)	MBC <sup>6</sup>	1	systemic (local)	single-site	very high	Resistance in <i>Botrytis</i> documented
thiram	dithiocarbamates	M3	contact	multi-site	low	
triflumizole (Procure)	DMI <sup>3</sup>	3	systemic (local) <sup>2</sup>	single-site	medium	

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 Generally considered to have systemic action based on performance data but has not been proven experimentally.

3 DMI = demethylation (sterol) inhibitor

4 QoI = quinone outside inhibitor (strobilurin)

5 SDHI = succinate dehydrogenase inhibitor

6 MBC = methyl benzimidazole carbamate

Acknowledgment: Adaskaveg et al., 2017. *Efficacy and Timing of Fungicides, Bactericides, and Biologicals for Deciduous Tree Fruit, Nut, Strawberry, and Vine Crops.*

# FUNGICIDE EFFICACY (7/18)

Fungicide	Resistance risk (FRAC) <sup>1</sup>	Powdery mildew	Gray mold	Anthrac-nose	Angular leaf spot	Common leaf spot	Mucor rot	Rhizopus rot	Leather rot	Crown rot	Red stele
Bumper/Tilt <sup>8</sup>	high (3)	++++	---	++	---	+++	---	---	---	---	---
Luna Privilege	high (7)	++++	++++	ND	---	ND	ND	ND	ND	ND	ND
Luna Sensation	medium (7/11) <sup>2</sup>	++++	++++	ND	---	ND	ND	ND	ND	ND	ND
Luna Tranquility	medium (7/9) <sup>2</sup>	++++	++++	ND	---	ND	ND	ND	ND	ND	ND
Mettle	high (3)	++++	NR	ND	ND	ND	ND	ND	---	---	---
Procure	high (3)	++++	---	+	---	---	---	---	---	---	---
Quadris Top <sup>8</sup>	Medium (3/11)	++++	++	+++	---	---	ND	+	ND	ND	ND
Quilt Xcel,Avaris 2XS <sup>8</sup>	medium (3/11)	++++	++	+++	---	---	ND	+	ND	ND	ND
Quintec	high (13)	++++	---	---	---	---	---	---	---	---	---
Rally	high (3)	++++	---	++	---	++++**	---	---	---	---	---
Rhyme	high (3)	++++	---	NR	---	NR	NR	NR	NR	NR	NR
Torino	high (U6)	++++	---	---	---	---	---	---	---	---	---
Abound <sup>7,8</sup>	medium (11) <sup>2</sup>	+++	++	+++	---	---	ND	ND	ND	ND	ND
Cabrio	medium (11) <sup>2</sup>	+++	++	++	---	---	ND	ND	ND	ND	ND
Evito	medium (11) <sup>2</sup>	+++	++	++	---	---	ND	ND	ND	ND	ND
Fontelis	high (7)	+++	++++	ND	ND	ND	ND	ND	ND	ND	ND
Kenja	high (7)	+++	++++	ND	ND	ND	ND	ND	ND	ND	ND
Merivon <sup>8</sup>	medium (7/11) <sup>2</sup>	+++	++++	ND	---	---	ND	ND	ND	ND	ND
Ph-D,Oso	medium (19)	+++	++	++	ND	ND	---	---	---	---	---
Pristine <sup>8</sup>	medium (7/11) <sup>2</sup>	+++	++++	ND	---	---	ND	ND	ND	ND	ND
Sulfur	low (M2)	+++	---	---	---	---	---	---	---	---	---
Topsin-M,T-Methyl,Incognito	very high (1) <sup>2</sup>	+++	+++	---	---	++	---	---	---	---	---
Velum One <sup>10</sup>	high (7)	++	+	ND	---	ND	ND	ND	ND	ND	ND
Captan	very low (M4)	+/-	++++	+++	---	---	+	---	---	---	---
Elevate	high (17) <sup>2,6</sup>	+/-	++++ <sup>6</sup>	+	---	---	---	---	---	---	---
Aliette <sup>3,7</sup> ,Legion**	low (33)	---	---	---	---	---	---	---	+++	++	++
Bravo	low (M5)	---	NR	++	NR	+++	NR	NR	NR	NR	NR
Captevate	medium (M4/17) <sup>2</sup>	---	+++	+++	---	---	+	---	---	---	---
Copper	low (M1)	---	---	---	+++ <sup>5</sup>	---	---	---	---	---	---
Fungi-Phite, K-Phite, Prophyt	low (33)	---	---	---	---	---	---	---	+++	++	++
Ridomil Gold SL <sup>4</sup>	high (4) <sup>2</sup>	---	---	---	---	---	---	---	+++ <sup>4</sup>	++	++
Rovral,Ipro-dione,Nevado	low (2)	---	+++	---	---	---	++	---	---	---	---
Switch <sup>7</sup>	high (9/12)	---	++++	+++	---	---	+	+++	---	---	---
Thiram	low (M3)	---	++	++	---	---	---	---	---	---	---

BIOLOGICALS/ NATURAL PRODUCTS											
Fracture	low	++	+	----	----	----	----	----	----	----	----
Serenade ASO, Serenade Opti	low	++	+	----	----	----	----	----	----	----	----
Actinovate <sup>7</sup>	low	+	----	+	----	----	----	----	----	----	----
Cinnacure	low	+	----	----	----	----	----	----	----	----	----
Double Nickel	low	+	----	----	----	----	----	----	----	----	----
M-Pede	low	+	----	----	----	----	----	----	----	----	----

**Rating:** +++++ = excellent and consistent; +++ = good and reliable; ++ = moderate and variable; + = limited and/or erratic; +/- = minimal and often ineffective; ---- = ineffective; NR = not registered; and ND = no data.

**\*\* Not registered, label withdrawn or inactive in California.**

- <sup>1</sup> 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.
- <sup>2</sup> To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications/season.
- <sup>3</sup> Foliar applications provide systemic treatment.
- <sup>4</sup> Ridomil Gold SL is the only formulation registered. If the GR formulation is applied to a previous crop that must be removed, it has a 0-day plantback interval.
- <sup>5</sup> More than 4 applications causes severe stunting.
- <sup>6</sup> Nonpersistent resistant populations of *Botrytis cinerea* to fenhexamid occur with repeated use of FRAC group 17 fungicides.
- <sup>7</sup> Plant dip (nurseries) or foliar spray (field use).
- <sup>8</sup> Not for use in nurseries, on nursery transplants, or greenhouses (check label for details).
- <sup>9</sup> Bravo is registered under a 24c special local needs for nursery use only on non-bearing plants. It is used as a dip treatment of transplants.
- <sup>10</sup> Velum One is a fluopyram formulation for chemigation. Soil applications are designed for nematode management but may also suppress powdery mildew.

Acknowledgment: Adaskaveg et al., 2017. *Efficacy and Timing of Fungicides, Bactericides, and Biologicals for Deciduous Tree Fruit, Nut, Strawberry, and Vine Crops.*

## MOST EFFECTIVE TREATMENT TIMINGS FOR KEY DISEASES (7/18)

**Note:** Not all indicated timings may be necessary for disease control.

Disease	Preplant fumigation <sup>2</sup>	Clean nursery stock	Fungicide At Planting		Fungicide Preharvest <sup>1</sup>	
			Dips or water washing	Before overhead irrigation	Foliar	Fruit
Angular leaf spot	+	+++	+	+++	+	—
Anthracnose <sup>3</sup>	+++	+++	+++	+	+	+++
Botrytis fruit rot <sup>3</sup>	—	—	—	+	++	+++
Common leaf spot <sup>3</sup>	+	+++	+++	+++	+++	+
Fusarium wilt	+++	++	—	—	—	—
Leather rot <sup>4</sup>	+++	—	—	++	—	++
Macrophomina crown rot	+++	++	—	—	—	—
Mucor fruit rot	—	—	—	+	+	+++
Powdery mildew <sup>3</sup>	—	+++	—	—	+++	+
Phytophthora crown rot <sup>4</sup>	++	++	++ (dip)	++	+	—
Red stele <sup>4</sup>	++	++	—	+	++	—
Rhizopus rot (Leak)	—	—	—	—	—	+++
Verticillium wilt	+++	++	—	—	—	—

Rating: +++ = most effective; ++ = moderately effective; + = least effective; — = ineffective

1 Preharvest treatments include applications of fungicides before heavy fog, dews, or rain.

2 Preplant fumigation includes chloropicrin, 1,3-dichloropropene/chloropicrin, or chloropicrin; followed by metam sodium or metam potassium. Alternatively, make solitary applications of 1,3-dichloropropene/chloropicrin or chloropicrin.

3 To reduce risk of fungicide resistance development, use an integrated program that includes a rotation of fungicides with different modes of action.

Acknowledgment: Adaskaveg et al., 2017. *Efficacy and Timing of Fungicides, Bactericides, and Biologicals for Deciduous Tree Fruit, Nut, Strawberry, and Vine Crops.*

## *Insects and Mites*

(Section reviewed 7/18)

### **APHIDS** (7/18)

#### **Scientific Names:**

Green peach aphid: *Myzus persicae*

Melon aphid: *Aphis gossypii*

Potato aphid: *Macrosiphum euphorbiae*

Strawberry aphid: *Chaetosiphon fragaefolii*

#### **DESCRIPTION OF THE PESTS**

Strawberry aphid is pale green to yellow. Both adults and nymphs have transverse striations (horizontal lines) across the abdomen and are covered with knobbed hairs that are readily seen with a hand lens. These striations and hairs are not found on any of the other aphid species infesting strawberry.

Melon aphid is small, globular, and color varies from yellowish green to greenish black. This species is often the first to migrate into the strawberry fields each season and is the most difficult aphid species to control with insecticides.

Green peach aphid and potato aphid are less common in strawberries than the other species. The green peach aphid is green to greenish yellow and is more streamlined than the rounded melon aphid. Winged adults typically have a black spot on the top of the abdomen that is easy to see with a hand lens.

The potato aphid is much larger than the other species and has both a pink form and a green form in California. The long legs on this species give it a characteristic spiderlike appearance.

#### **DAMAGE**

Aphid numbers usually peak during late March in Central and Southern California and undergo a natural decline to economically insignificant levels during May and June. In high-elevation nurseries, numbers peak in mid- to late summer. Numbers may continue to increase to damaging levels when spring temperatures are moderate and humidity is high.

In California strawberry production fields, aphids rarely reach damaging levels but occasionally cause yield losses because of honeydew contamination. Honeydew deposition on fruit causes sooty molds to develop and the white skins shed by aphid nymphs to stick to the fruit. This contamination renders the fruit unmarketable as fresh fruit.

Aphids transmit several viruses that can cause significant economic losses in strawberries if the planting remains in the field for several years. While not a serious problem in annual production plantings, aphid transmission of viruses is a major concern for nursery production.

#### **MANAGEMENT**

While biological control can help to keep aphid numbers low, insecticide applications may be necessary in Southern California, and occasionally in Central Coast fields, if spring weather is conducive to their development. Insecticides are also applied in strawberry nurseries to prevent aphid buildup and virus spread. In other strawberry fruit production areas, aphids rarely reach damaging numbers and are not treated.

#### **Biological Control**

A complex of at least seven species of primary parasites have been reared from aphids infesting strawberry plants. However, the parasites themselves are attacked by a large number of hyperparasite species (parasites of the parasites) that limit the buildup of primary parasites.

Generalist predators such as syrphid fly or green lacewing larvae often provide a greater level of control. Lacewings can be purchased and released to help control aphids but research is lacking on the efficacy of augmentative releases against aphids. Naturally occurring biological controls can keep aphid numbers below economically damaging levels, such as with the case of the melon aphid in Southern California strawberry-growing regions, so consider parasite and predator numbers before any treatment decision is made.

## Cultural Control

- Control dust (e.g., with water sprays on driveways or with cereal crops at ends of beds) to facilitate parasite and predator activity.
- Avoid excess nitrogen fertilizer, as aphid numbers tend to be especially high in plants that receive too much nitrogen.
- Some row covers (plastic tunnels or Remay-type enclosures) reduce aphid numbers to below economic levels, but the costs can be a limiting factor for large- or even small-scale plantings.

## Organically Acceptable Methods

Use cultural and biological controls and sprays of insecticidal soap, azadirachtin (Neemix), neem oil (Trilogy), and pyrethrin (PyGanic) on organically certified strawberries.

## Monitoring and Treatment Decisions

- In strawberry nurseries, consider controlling aphids as soon as they appear on the plants, to reduce the spread of viruses, especially for the earliest generations.
- In Southern California, start taking weekly samples when the first leaf is fully expanded. Remove the oldest trifoliolate leaf and record if any aphids are present. It is not necessary to count the aphid numbers. Randomly sample 40 trifoliolate leaves per acre and calculate the percent of leaves that have aphids. Apply insecticide if the infestation level reaches 30%.
- In the Central Coast, aphids rarely reach damaging levels. If aphid numbers appear to be increasing, an insecticidal soap spray will help reduce the aphid numbers with minimal damage to natural enemies. Take a newly unfolded leaf from each plant sampled for mites and count the number of aphids. If numbers reach an average of 10 per leaf, apply insecticidal soap.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. FLUPYRADIFURONE (Sivanto prime) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4D	7–14 oz	12	0
B. IMIDACLOPRID (Admire Pro, soil) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: Apply to root zone through drip, trickle, or microsprinkler irrigation after plants are established or on perennial crops in early spring before bud opening. Or, just before or during transplanting, treat plant or plant hole. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging. ... or ... (Admire Pro, foliar) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: For resistance management an application of Admire (soil or foliar) or Actara to the same crop is not recommended. Do not make foliar treatments when bees are actively foraging, or up to 10 days before bloom.	10.5–14 fl oz	12	14
C. THIAMETHOXAM (Actara) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: For resistance management an application of Admire (soil or foliar) or Actara to the same crop is not recommended. Do not make foliar treatments when bees are actively foraging or up to 10 days before bloom.	1.5–3 oz	12	3
D. ACETAMIPRID (Assail 70WP) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: Do not exceed more than 0.5 lb a.i./acre per growing season. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	0.8–1.7 oz	12	1

**ORGANIC OPTIONS** (Efficacy research may be lacking on these products)



Common name (Example trade name)	Amount per acre	REI† (hours)	PHI‡ (days)
A. AZADIRACTIN# (Neemix) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un	5–7 fl oz	4	0
B. HORTICULTURAL OIL# (Organic JMS Stylet Oil) MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: Amount is for 100 gal/acre; may use up to 150 gal/acre water carrier. Spray with ground equipment for optimum coverage of leaf surfaces. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Heed label warnings about compatibility with other pesticides.	3 qt	4	0
C. NEEM OIL# (Trilogy) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : — COMMENTS: Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1–2%	4	0
D. PYRETHRIN# (PyGanic 1.4 EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A COMMENTS: Buffer final spray to a pH of 5.5 to 7.0. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	16–64 fl oz	12	0
E. INSECTICIDAL SOAP# (M-Pede) MODE OF ACTION: A contact insecticide with smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. In any case, do not make more than two applications per season. A single application should reduce aphid numbers about 50%. Also kills about 50% of predatory mite eggs, but it does not affect the motile stages so populations of these mites should recover.	2.5 fl oz/gal water	12	0

† Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://www.irac-online.org/>.

# BEET ARMYWORM (7/18)

**Scientific Name:** *Spodoptera exigua*

## DESCRIPTION OF THE PEST

The beet armyworm adult is a gray and brown moth that lays its masses of round, pale-colored eggs beneath a covering of hairlike fluff collected from their wings. Newly hatched armyworms are often green and feed in groups, skeletonizing the undersides of leaves. Older beet armyworm larvae are green and smooth skinned with light stripes lengthwise along their sides. They commonly have a black spot on their side above the second leg.

## DAMAGE

Moths from overwintering larvae lay eggs in spring (late winter in Southern California). Young larvae feed on foliage and crowns before attacking berries. Damage most commonly occurs in Southern California and Santa Maria growing areas, but damage can be serious in any region if larvae feed on the crowns of newly transplanted strawberry plants. Feeding at this time can kill the young transplants. Damage also can occur to summer-planted strawberries. Fall populations of adult females often fly into strawberry fields to lay eggs. Newly hatched armyworms feed on foliage, skeletonizing the upper or lower leaf surfaces next to their egg mass. Beet armyworm numbers can become greater in previously infested second-year plantings and damage fruits in spring. Larger armyworms feed directly into the berries, while smaller armyworms often feed on the shoulder of the berry beneath the calyx sepals.

## MANAGEMENT

As with lygus and cutworm management, weed control in and around fields is an important aspect of managing armyworms. Insecticides may be necessary in Southern California if beet armyworm numbers are high around the time of transplanting. At other times, consider the level of parasitism and mortality from disease before making the decision to spray for beet armyworm.

### Biological Control

Young beet armyworms can be heavily parasitized by the ichneumonid parasitic wasp, *Hyposoter exiguae*. This parasite can easily be monitored in the armyworm populations by simply pulling young worms apart and looking for the parasite larva inside. In addition, armyworms often become diseased with a virus that can cause high mortality; larvae turn black when killed by the virus. High natural mortality translates to few mature larvae surviving to cause further damage.

### Cultural Control

Because adult moths are attracted to weeds for egg laying, good weed control helps minimize armyworm numbers.

### Organically Acceptable Methods

Use cultural and naturally occurring biological controls, and sprays of *Bacillus thuringiensis* ssp. *aizawai* or the Entrust formulation of spinosad on organically certified strawberries.

### Monitoring and Treatment Decisions

In Southern California and the Santa Maria growing area, plants are most vulnerable to beet armyworms soon after transplanting when larval feeding in the crown can kill the young transplants. Monitor beet armyworm flights with pheromone traps just before and after transplanting. If moth catches indicate a lot of beet armyworm activity, examine young strawberry plants for egg masses and time treatments to egg hatch.

At other times of the year and in other areas, if large numbers of predators, parasites, or virus are present, delay spraying to determine if armyworms will be controlled by natural enemies.

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI† (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
A. METHOXYFENOZIDE (Intrepid 2F) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 18	6–12 fl oz	4	3
B. SPINETORAM (Radiant SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Rotate to an insecticide with a different mode of action after two successive applications of either spinetoram or spinosad to help delay the development of resistance to group 5 insecticides. The use of this insecticide may best be reserved for control of western flower thrips because the options are more limited for this pest. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	6–10 fl oz	4	1
C. SPINOSAD (Entrust)# (Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Most effective against younger larvae. Rotate to an insecticide with a different mode of action after two successive applications. Maintaining proper pH of the spray tank water is critical for maximum efficacy. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.25–2 oz 4–6 fl oz	4 4	1 1
D. <i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (Deliver) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Spray when armyworms are still small. To be effective, <i>Bacillus thuringiensis</i> must be applied no later than the second instar stage.	0.5–1.5 lb	4	0
E. <i>BACILLUS THURINGIENSIS</i> ssp. <i>AIZAWAI</i> # (Agree WG, Xentari) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Spray when armyworms are still small. To be effective, <i>Bacillus thuringiensis</i> must be applied no later than the second instar stage.	0.5–2 lb	4	0
F. DIAZINON* (Diazinon AG600 WBC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Do not allow this insecticide to run off into surface waters. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	12.75 fl oz/100 gal water	72 (3 days)	5

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

# Acceptable for use on organically grown produce.

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

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## CABBAGE LOOPER (7/18)

**Scientific Name:** *Trichoplusia ni*

### DESCRIPTION OF THE PEST

Loopers are green caterpillars that have a narrow, white stripe along each side and several narrow lines down the back; they move with a characteristic arching or looping motion with the help of three pairs of true legs in the front and three pairs of false legs towards the end. Eggs are similar in appearance to corn earworm eggs but are flatter and laid singly on the undersides of leaflets. Adult moths have brown, mottled forewings marked in the center with a small, silver figure 8.

### DAMAGE

Young larvae feed primarily on the undersides of leaves, skeletonizing them. High numbers can damage fruit, but this is very uncommon.

### MANAGEMENT

Insecticide applications for loopers are seldom necessary in strawberries because they are frequently controlled by naturally occurring parasitic wasps and seldom feed on fruit. If insecticide applications are necessary, time them to egg hatch.

#### Biological Control

Loopers are commonly controlled by parasitic wasps *Hyposoter exiguae*, *Copidosoma truncatellum*, and *Trichogramma* spp., and by outbreaks of nuclear polyhedrosis virus.

#### Organically Acceptable Methods

Use biological controls, as well as sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad on organically certified strawberries.

#### Monitoring and Treatment Decisions

Cabbage looper is most likely to become a pest in strawberries when the field is planted next to lettuce fields. There are no established treatment thresholds for cabbage loopers in strawberries. If an insecticide application is necessary, the preferred practice is to apply *Bacillus thuringiensis* just after egg hatch. Eggs are often found when monitoring mites with a leaf-brushing machine. Save a few leaves with eggs and observe when egg hatch begins and apply an insecticide. When monitoring other pests, look for signs of looper feeding such as leaflets with holes, feces, and caterpillars feeding at the edge of a hole.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<p><i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i></p>			
A. <i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (Various products) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Use when loopers are in the first or second instar stage. Apply to plants when they are dry.	Label rates	4	0
B. <i>BACILLUS THURINGIENSIS</i> ssp. <i>AIZAWAI</i> # (Agree WG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A	Label rates	4	0
C. SPINOSAD (Entrust)# (Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Most effective against younger larvae. Rotate to an insecticide with a different mode of action after two successive applications. Maintaining proper pH of the spray tank water is critical for maximum efficacy. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.25–2 oz 4–6 fl oz	4 4	1 1
D. METHOXYFENOZIDE (Intrepid 2F) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 18	6–12 fl oz	4	3

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## CORN EARWORM (7/18)

**Scientific Name:** *Helicoverpa* (= *Heliothis*) *zea*

### DESCRIPTION OF THE PEST

Adult corn earworms are grayish-brown moths with a wingspan of about 1.5 inches. The corn earworm can be found in all strawberry-growing areas but is primarily a problem in coastal Southern California. There, adults emerge from overwintering pupae in large numbers each spring, often early March to mid-April. Each female can produce 500 to 3000 spherical eggs with rows of ridges along the sides.

The eggs, which are usually laid singly on the undersides of younger leaves, are initially white but then develop a brown ring near the top before hatching. When temperatures are warm, eggs may hatch within 2 or 3 days. A newly hatched corn earworm has a black head and rows of dark-colored tubercles and bristles along the body; older larvae exhibit a wide variation in color, ranging from green, pink, or brown to nearly black. The time needed to complete a generation is temperature dependent but often takes about 1 month.

### DAMAGE

Corn earworms damage strawberries by burrowing into fruit. Although there are several generations each season, only larvae of the overwintering generation attack Southern California strawberries in spring. Entrance holes made by early instar larvae are not visible, and the fruit must be cut to determine their presence. Larvae typically feed in the air pocket at the fruit's center; mature fruit containing large larvae appear seedy and develop a shrunken surface with one or more brown patches. Contamination of the fruit prevents it from being marketed as fresh or processed fruit; federal tolerance currently requires downgrading to juice stock if a single 7 mm or larger larva is found per 44 pounds of fruit (about 1,100 berries).

### MANAGEMENT

Management of corn earworm may become necessary in South Coast strawberries, especially following a mild winter. Corn earworm becomes more of a problem as the season progresses, especially in April and later and when temperatures start to warm. They can be especially problematic when fruit is directed to processing because of lengthened harvest intervals and lack of insecticides being applied for other pests. Monitor for healthy and parasitized eggs in spring to determine the need for insecticides.

#### Biological Control

A number of predaceous insects and parasites will feed on corn earworm eggs. A tiny parasitic wasp, *Trichogramma pretiosum*, has been found developing in *Helicoverpa* eggs on strawberries, but the percent parasitization from natural populations appears to be low. *Trichogramma* can be purchased from commercial sources for augmentative release. The frequency of release and release rates to effect control, however, have not been determined on strawberries. If *Trichogramma* are purchased for release, check for the quality of the emerging adults. The minute pirate bug is a predator that has been observed to feed on corn earworm eggs. While both of these biological control agents can provide some pest suppression, the very low tolerance for insect contamination in strawberries makes this control option less attractive when earworm numbers are high.

#### Cultural Control

Planting early maturing sweet corn cultivars at the edges of strawberry fields as "trap crops" may reduce strawberry contamination by the corn earworm. Female moths strongly prefer to lay eggs on corn silk, so silking must coincide with the period of strawberry fruit susceptibility. Planting corn at different times may be necessary to extend the period when the corn is silking, and the corn must be removed following silking to destroy trapped larvae.

#### Organically Acceptable Methods

Use biological and cultural control methods and sprays of the Entrust formulation of spinosad and *Bacillus thuringiensis* on organically certified strawberries.

#### Monitoring and Treatment Decisions

Monitor the first generation of this pest in South Coast strawberries.

- Use Texas-style *Heliothis* pheromone traps to monitor emergence and flight activity of moths beginning in late February and early March.

- Begin surveying strawberries or trap crops for eggs when 10 or more adults are trapped in a period of 1 week.
  - If unparasitized eggs are found in the strawberry field, consider spraying.
- Most insecticides are more effective against early instars, so detecting hatch is important. On average, it takes 147 degree-days greater than 55°F for the larvae to develop from newly hatched larvae to fourth instars. For heavy infestations, insecticide applications may need to be repeated at 10- to 14-day intervals, depending on the residual activity of the product applied.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. METHOXYFENOZIDE (Intrepid 2F) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 18	6–12 fl oz	4	3
B. SPINETORAM (Radiant SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Rotate to an insecticide with a different mode of action after two successive applications of either spinetoram or spinosad to help delay the development of resistance to group 5 insecticides. The use of this insecticide may best be reserved for control of western flower thrips because the options are more limited for this pest. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	6–10 fl oz	4	1
C. SPINOSAD (Entrust)# (Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Most effective against younger larvae. Rotate to an insecticide with a different mode of action after two successive applications. Maintaining proper pH of the spray tank water is critical for maximum efficacy. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.25–2 oz 4–6 fl oz	4 4	1 1
D. NOVALURON (Rimon 0.83 EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 15 COMMENTS: An insect growth regulator. Apply when the majority of the population is at egg hatch to the second instar.	9–12 fl oz	12	1
E. <i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (Various products) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Most effective against newly hatched larvae and not very effective against large larvae and those that have already entered the fruit to feed. Carefully time treatments to egg hatch. Because residual activity is short, it may be necessary to repeat applications at 4- to 7-day intervals during extended periods of peak egg hatch.	Label rates	4	0
F. <i>BACILLUS THURINGIENSIS</i> ssp. <i>AIZAWAI</i> # (Agree WG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A	Label rates	4	0

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

# Acceptable for use on organically grown produce.

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI† (days)
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<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.



## CUTWORMS (7/18)

**Scientific Names:** Black cutworm: *Agrotis ipsilon*  
 Roughskinned cutworm: *Athetis mindara*  
 Variegated cutworm: *Peridroma saucia*

### DESCRIPTION OF THE PESTS

The black cutworm, also called the greasy cutworm, is the primary cutworm pest of strawberries in most growing areas, but other species occur in damaging numbers on occasion. Cutworm adults are large moths, usually brown or gray, about 1.5 inches long. Mature larvae are robust, nearly 1.5 inches long, and their smooth skin is either mottled brown or gray. Larvae tend to fall to the ground and curl up into a C-shape when they are disturbed.

Cutworms are active night feeders and can be found hidden in the soil at the base of the plant during the day. Most cutworms overwinter in strawberries as young larvae, maturing and pupating in spring. Since there are only a limited number of hosts in fall for adult moths to lay eggs on, they tend to move into newly planted strawberry fields. Migration of adult moths can also occur following harvest of other hosts, such as lettuce, in nearby fields.

### DAMAGE

Early season damage by newly hatched cutworms generally appears as small, webless perforations in the newly expanding crown leaves. As larvae grow, they begin their characteristic stem cutting along with chewing larger, irregular holes in the foliage. At times, serious damage can occur to the plant crown when the central growing point of young plants is eaten.

Damage often occurs along the edges of fields adjacent to residential areas or to more favored crops such as lettuce or beans. Most damage occurs in fall and spring, with the fall attack being more destructive. During harvest, cutworms can cause rather pronounced holes in the fruit. Damaged berries tend to be concentrated in localized areas of one to several plants around each active cutworm.

### MANAGEMENT

Watch edges of fields to detect cutworm invasions. Controlling weeds in and around the field is important to manage this pest. If damage is occurring, use insecticidal baits or make spot treatments.

#### Biological Control

Other than birds, there isn't much significant biological control known. The most important control is cultural.

#### Cultural Control

Weed control is paramount to preventing a serious cutworm problem. Weedy fields tend to attract more moths to lay their eggs. Annual planting and thorough pruning of second-year plantings reduce survival of overwintering larvae.

#### Organically Acceptable Methods

Use cultural controls and sprays of *Bacillus thuringiensis* or the Entrust formulation of spinosad on organically certified strawberries.

#### Monitoring and Treatment Decisions

There is no specific threshold for treating cutworms. Damage tends to be localized, so spot treating is recommended if using foliar sprays. For best results when applying foliar sprays, spray late in the day or evening. When using insecticidal baits, make applications immediately after weeding when evidence of substantial leaf or stem cutting is noted in order to prevent migration to the crop plants.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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Not all registered pesticides are listed. *The following 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. Always read the label of the product being used.

**BAITS**

A.	SPINOSAD (Seduce) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS:	Label rates	4	1
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**FOLIAR SPRAYS**

A.	MALATHION (Malathion 8E) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Some formulations can be applied through the drip lines, which allows application under the plastic where cutworms can hide. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	Label rates	12	3
B.	DIAZINON* (Diazinon AG600 WBC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Do not allow this insecticide to run off into surface waters. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	12.75 fl oz/100 gal water	72 (3 days)	5
C.	SPINOSAD (Entrust)# (Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Apply against younger larvae or when fruit feeding is observed. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.25–2 oz 4–6 fl oz	4 4	1 1
D.	<i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (various products) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Spray when young larvae present. Good coverage at relatively low dilution is essential.	Label rates	4	0
E.	<i>BACILLUS THURINGIENSIS</i> ssp. <i>AIZAWAI</i> # (Agree WG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Spray when young larvae present. Good coverage at relatively low dilution is essential.	Label rates	4	0

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## CYCLAMEN MITE (7/18)

**Scientific Name:** *Phytonemus pallidus*

### DESCRIPTION OF THE PEST

At low numbers, cyclamen mites (Family: Tarsonemidae) are usually found along the midvein of young, unfolded leaves and under the calyx of newly emerged flower buds; when numbers increase, these mites can be found anywhere on nonexpanded plant tissues. They are not visible to the naked eye, and when mature, they only measure about 0.01 inch (0.25 mm) long. Mature mites are pinkish orange and shiny. The hind legs are thread- or whiplike in the female and grasping or pincerlike in the male. Eggs are translucent and comparatively large.

Adult females lay about 90 eggs, 80% of which develop into females. During summer, newly hatched mites develop into mature adults within 2 weeks. Cyclamen mite numbers increase rapidly soon after a field becomes infested. They overwinter as adult females in the strawberry crown and can be present on transplants if the nursery field was infested.

Cyclamen mite can be distinguished from nondamaging tarsonemid mites in the genus *Tarsonemus* through microscopic examination, by examining the fourth femur of male mites. The cyclamen mite has a "flange" or distinct bulge present while the males of both *Tarsonemus* species do not.

### DAMAGE

Cyclamen mites are primarily pests in fall-planted and second-year plantings, but they can be transplanted into first-year fields and the damage symptoms become apparent on leaves as the season progresses. Leaves heavily infested with cyclamen mites become severely stunted and crinkled, resulting in a compact leaf mass in the center of the plant. Feeding on flowers can cause them to wither and die. Fruit on infested plants is dwarfed, and the seeds stand out on the flesh of the berry. When uncontrolled, this mite can prevent plants from producing fruit.

### MANAGEMENT

Management of cyclamen mite requires carefully timed sprays of miticides that do not harm natural enemies. Prevent its introduction into strawberry fields by following good cultural practices. Propagating nursery stock free of cyclamen mites is essential to prevent their introduction to fruit-producing fields. This mite may survive in furrows of fields that have been bed fumigated. Because other nondamaging tarsonemid mite species, including *Tarsonemus setifer* and *Tarsonemus confusus*, occur in strawberry fields and it is very difficult to distinguish one species from another, focus control efforts in those fields where damage symptoms occur.

#### Biological Control

Two naturally occurring predatory mites of cyclamen mite are *Typhlodromus bellinus* and *T. reticulatus*, but their numbers increase too slowly to provide economic control. Early season releases of the commercially available predatory mite, *Amblyseius californicus*, may be able to control this pest mite. *Amblyseius cucumeris* releases have not proven to be effective.

When pest numbers are high, the sixspotted thrips, minute pirate bugs, and western predatory mite (*Galendromus occidentalis*) all feed on cyclamen mite.

#### Cultural Control

Pickers, bees, birds, and equipment, including strawberry freezer trays, can easily transfer cyclamen mites from one location to another. It may be worthwhile to dip trays of long-term cold storage (28°F) transplants into a hot water bath for 7 minutes right before planting to prevent infestation. (Infested nursery plants are the major source of this pest in annual plantings; be sure to use uninfested nursery stock.) To prepare plants for this treatment:

1. Thoroughly wash them to remove all dirt.
2. Place them in a circulating water bath that is held at a constant temperature of 120°F.
3. Submerge them in very cold water.
4. Plant them as soon as possible.

(This treatment is not recommended for fresh-dug transplants that have only been stored at 33°F.)

Avoid second-year plantings in problem areas. To slow the spread of infestations, rogue infested plants as soon as symptoms appear.

## Organically Acceptable Methods

Use biological and cultural control methods on organically certified strawberries.

## Monitoring and Treatment Decisions

If any damage symptoms are observed, be sure to monitor the rest of the field carefully to determine the extent of the infestation.

- Monitor newly unfolding leaves.
- Spray the area of the field where infestation is expected when densities of one cyclamen mite in 10 leaves are found.

To control cyclamen mites, a high volume of water per acre (300–500 gal) is necessary to soak the folded leaves and immature flower buds located in the crowns. Effective control requires a high rate of kill because numbers of this mite can increase rapidly. Roguing and spraying infested hot spots with a hand-sprayer can be useful in suppressing infestations without having to spray the entire field. In nurseries, early season control before plant canopy closes over is critical.

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI‡ (days)
<p><i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i></p>			
A. ABAMECTIN* (Agri-Mek SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 6 COMMENTS: Toxic to predatory mites and relatively toxic to parasites, but fairly safe for general predators. Apply in up to 600 gal water/acre to soak the pesticide into the crown of the plant. Works poorly under cold weather conditions. Make two applications 7 to 10 days apart when mites reach detectable levels under warmer temperatures in late winter or spring. Repeat this sequence of applications if necessary to maintain cyclamen mite control. Do not repeat treatment within 21 days of second application. Not registered for strawberry nurseries. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	3.5 fl oz	12	3
B. ACEQUINOCYL (Kanemite 15 SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 20B COMMENTS: Control does not become evident until 48 to 72 hours after application. Do not use less than 100 gal water/acre and do not apply more than twice per year. Allow a minimum of 21 days between treatments. Crops other than strawberries may not be rotated for at least 1 year following treatment.	31 fl oz	12	7
C. FENPYROXIMATE (FujiMite 5EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 21A COMMENTS: FujiMite provides an alternative mode of action to manage development of resistance in mites. Although it is a contact insecticide, it is effective on all developmental stages of mites. It is active on all important mite species including: two-spotted spider mite, Lewis mite, and cyclamen mite. FujiMite is toxic to predatory mites but is non-toxic to most other natural enemies. Spray coverage is key in obtaining maximum results.	2 pt	12	1
D. SPIROMESIFEN (Oberon 2SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 23	12–16 fl oz	12	3

† Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.

Common name (Example trade name)	Amount per acre	REI# (hours)	PHI# (days)
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<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## EUROPEAN EARWIG (7/18)

**Scientific Name:** *Forficula auricularia*

### DESCRIPTION OF THE PEST

Earwigs feed at night and can be found hidden inside split fruit and around crowns of plants during the day. They are slender brown insects, about 0.5 to 0.75 inch (13–19 mm) long. They have a conspicuous pair of pincers attached to the back end of the abdomen. The adults' wing covers are short and leathery. The pest becomes most destructive as nymphs approach maturity from April to July.

### DAMAGE

Earwig feeding results in small deep holes in the fruit that can only be distinguished from slug damage by the absence of slime. They will also inhabit cat-faced or open-ended fruit.

### MANAGEMENT

To control earwigs, destroy rubbish (e.g. discarded wood or other debris) near strawberry fields to prevent hiding places for them. In South Coast areas, earwigs may become a problem when they are present inside split fruit at harvest.

Earwigs can be monitored using inverted containers that are filled with shredded paper and have holes located near their bases. Examine the containers by removing the shredded paper to look for earwigs that have sought shelter. You can also use small cans, about one-third filled with vegetable oil containing a small amount of bacon grease or fish oil. Earwigs are attracted by the bacon grease or fish oil, fall into the vegetable oil, and suffocate. If significant numbers of earwigs are present, apply bait to the tops of beds, between plants.

### Organically Acceptable Methods

Keep strawberry fields clear of rubbish and plant debris for organically certified strawberries.

# GARDEN SYMPHYLAN (7/18)

**Scientific Name:** *Scutigerella immaculata*

## DESCRIPTION OF THE PEST

Garden symphylans are slender and white, they have 10 to 12 pairs of legs and a pair of antennae. They run rapidly when exposed to light. They occur mainly in moist soils with good structure and a high organic matter content and are often associated with debris from a previous crop that is not completely decomposed. They retreat to deeper soil levels during fallow periods and return to the root zone after crops are planted.

## DAMAGE

Garden symphylans damage plants by feeding on roots, thus retarding plant growth. They damage the same area every season, so infestations spread slowly and are usually only a problem in fields that were not fumigated or if the fumigation was ineffective.

## MANAGEMENT

Soil fumigation for pathogen and weed seed control will kill symphylans. In nonfumigated fields and fields with large amounts of crop residue from the previous crop, continuous flooding for 3 weeks in the summer helps to reduce infestations and discing in a crop of sorghum has been reported to reduce infestations in other crops. In organic fields, however, the best strategy is to avoid fields that have symphylans in the soil.

Research from other areas of the country indicates that symphylans can be detected with bait trapping. Either carrots or potatoes can be used as the bait. Cut the bait in half longitudinally and scratch the cut surface just before placing it in a shallow hole on the soil to ensure that the surface is moist. (Be sure that when the hole is created, the soil pores or spaces aren't sealed closed. Symphylans use these spaces to travel to the bait.) Cover the bait with a pot. 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 an insecticide application. Because the recommended treatment is best applied before transplanting, bait traps for symphylans a few weeks before transplanting.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

A. DIAZINON*			
(Diazinon AG 500)	1 qt	72 (3 days)	5
(Diazinon 50W)	2 lb	72 (3 days)	5
MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B			
COMMENTS: Broadcast before transplanting and incorporate into top 4 inches of soil. Application after transplanting is less effective, and diazinon must be well watered into the soil. Do not allow this product to run off into surface waters. Highly toxic to bees.			

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

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## LEAFROLLERS (7/18)

**Scientific Names:** Garden tortrix: *Ptycholoma* (= *Clepsis*) *peritana*  
 Orange tortrix: *Argyrotaenia franciscana* (= *A. citrana*)  
 Apple pandemis: *Pandemis pyrusana*  
 Light brown apple moth: *Epiphyas postvittana*  
 (and others)

### DESCRIPTION OF THE PESTS

Several leafrollers in the family Tortricidae are present in strawberry and vegetable-growing areas of the Central Coast. Of these species, the garden tortrix is the most likely to be found feeding on strawberry fruit. The orange tortrix and apple pandemis are primarily foliar feeders. The light brown apple moth, an introduced species, was first detected in the San Francisco and Monterey Bay areas in spring 2007.

Some leafrollers have only one generation in a year, but most leafrollers that feed on strawberry foliage have 2 to 4 generations a year, depending on species and location. When disturbed, these leafroller caterpillars wriggle vigorously.

#### Garden Tortrix

The adult garden tortrix is a buff-brown moth that is about 1/4 inch (6 mm) long. Each of the forewings is marked with a dark brown diagonal stripe and a marginal spot producing a chevron pattern when at rest. A faint whitish line borders the anterior edge of the brown stripe. This character and the overall lighter color distinguish adult garden tortrix from orange tortrix. The slender caterpillars of the garden tortrix are nearly 1/2 inch (13 mm) long when mature. Caterpillars have light brown to green bodies and light brown heads. The head has a small, distinct dark brown spot on each side. Larvae and pupae overwinter in debris around the base of the plant.

#### Orange Tortrix and Apple Pandemis

Adult orange tortrix and apple pandemis moths are about 1/2 inch (13 mm) long. Orange tortrix moths have light brown forewings. Apple pandemis moths have a series of lighter and darker rust colored V-shaped bands with the center band on the forewings edged with white. Apple pandemis caterpillars are green with yellowish green or straw-colored head capsules. Orange tortrix caterpillars have straw-colored to greenish bodies with a yellowish head capsule and prothoracic shield.

#### Light Brown Apple Moth

(View field identification guide available online at  
<http://www.ipm.ucanr.edu/PDF/PMG/LBAMinCANurseries.pdf>)

In both appearance and behavior, the light brown apple moth is similar to the other leafroller species. Adults are light brown, about 1/4 to 1/2 inch (6–13 mm) long and display variable patterns of dark brown on the wings. Like other tortricid moths, they have the typical bell-shaped wings while at rest. The caterpillar is pale to medium green and has a light brown head capsule. Fully-grown caterpillars are 1/2 to 3/4 inch (10–19 mm) long.

Updated information on light brown apple moth and regulatory quarantine procedures in California can be found at your county Agricultural Commissioner's office.

### DAMAGE

Most leafroller larvae, including the light brown apple moth, tie one or more strawberry leaves together with white webbing to create shelters. Larvae can also create shelters by folding leaves or the sepals of the calyx to fruit and may feed from these sheltered areas on the surface or internal tissues of fruit.

Early in the season, the garden tortrix serves a valuable function in breaking down and recycling old leaf and fruit litter. It generally does not cause significant damage when strawberry plants are small. However, as the leafroller numbers increase and the plant canopies close in, more ripening berries come in contact with trash where they may become exposed to the tortrix larvae. When this happens, larvae will often spin a nest in creases along the berry's surface and may chew small, shallow holes in the berry, incidental to their scavenging. Thus, as numbers increase in late spring or early summer, significant fruit losses can result from both larval contamination and secondary rots invading the feeding holes. During late June and July, contamination of south coast fields just before the berries are sent to the processors can be a serious problem. Fruit damage can appear similar to that caused by other Lepidoptera larvae including corn earworm, armyworms, and cutworms.



The light brown apple moth is unique; although damage caused is similar to other leafrollers, its detection in strawberry fields will result in restrictions shipping fruit out of the quarantine area.

## MANAGEMENT

In areas with a chronic tortrix problem, it may be feasible to remove accumulated trash in spring around the plants to limit the potential for a large increase in leafroller numbers. This is especially important in summer plantings and second year fields where it is more likely for leafrollers to be present.

Because it is difficult to distinguish the light brown apple moth larvae from other leafrollers in appearance and behavior, a preventive approach, consisting of sanitation, monitoring, and chemical treatments, targeting all leafrollers is currently suggested for strawberry fields within quarantine zones. This will ensure that no larvae will be present in harvested fruit. This approach will avoid shipment delays and possible loss of fruit marketability.

### Organically Acceptable Methods

Remove dead vegetation from strawberry fields to reduce overwintering populations. Use sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad on organically certified strawberries. Sprays of *Bacillus thuringiensis* can be more effective if applied multiple times at close intervals, because it exposes survivors of previous applications to another dose of this insecticide. Additionally, it can be helpful to lower water carrier volumes to concentrate the dose of the insecticide ingested by the larvae.

While the USDA–CDFA regulatory regime is in place for light brown apple moth, the use of mating disruption pheromone dispensers (Isomate LBAM Plus, Pacific Biocontrol Corporation) is strongly recommended for management and reduction of light brown apple moth in organic strawberry. The ‘twist ties’ type of dispensers should be applied evenly at the rate of 200 to 300 dispensers per acre above the canopy by attaching them to wires or tall sticks across the field.

### Monitoring and Treatment Decisions

There are several ways to monitor for leafrollers, including the light brown apple moth.

In the spring, before the commencement of harvest, begin monitoring by examining plants for larvae. Leaf rolls made by larvae are not hard to find and tend to consist of one or more (usually mid-aged) strawberry leaves webbed together. If a leafroller or the concomitant webbing is detected, it is recommended to search more thoroughly in the immediate vicinity of the initial find, because leafrollers often aggregate. Larvae in fruit can be detected during harvest. The infested fruit and larvae should be destroyed. Webbing under the calyx, frass, or holes in the fruit, all indicate leafroller activity. Fruits have to be observed closely, since early leafroller instars are exceedingly small and can hide under the calyx.

With all leafrollers, directed sprays that penetrate the foliage canopy at a sufficient volume are recommended. Because of the tendency to have overlapping generations, it is difficult to target a specific larval stage.

Garden tortrix larvae are particularly difficult to control with sprays, because they are found in the litter beneath the protective canopy of strawberry leaves.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

A. SPINOSAD (Entrust)#	1.25–2 oz	4	1
(Success)	4–6 fl oz	4	1
MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5			

COMMENTS: Most effective against younger larvae. Rotate to an insecticide with a different mode of action after two successive applications. Maintaining proper pH of the spray tank water is critical for maximum efficacy. Highly toxic to bees; 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	REI‡ (hours)	PHI‡ (days)
B. CHLORANTRANILIPROLE (Coragen) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 28	3.5–5.0 fl oz	4	1
C. <i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (Thuricide) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A COMMENTS: Spray when armyworms are still small. To be effective, <i>Bacillus thuringiensis</i> must be applied no later than the second instar stage.	Label rates	4	0
D. METHOXYFENOZIDE (Intrepid 2F) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 18	6–12 fl oz	4	3
E. SPINETORAM (Radiant SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Rotate to an insecticide with a different mode of action after two successive applications (Success and Entrust have the same mode of action). Maintaining proper pH of the spray tank water is critical for maximum efficacy. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	6–10 fl oz	4	1
F. DIAZINON* (Diazinon AG600 WBC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Do not allow this pesticide to run off into surface waters. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	12.75 fl oz/100 gal water	72 (3 days)	5

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

# Acceptable for use on organically grown produce.

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

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## LEWIS SPIDER MITE (7/18)

**Scientific Name:** *Eotetranychus lewisi*

### DESCRIPTION OF THE PEST

Lewis mite has emerged as an occasional pest of strawberries, primarily in Oxnard, Salinas, and other coastal production regions. Lewis spider mite, or Lewis mite, infests the undersides of strawberry leaves, where they may form colonies and produce light webbing when abundant. Lewis spider mites are very small (about 0.01–0.014 inch in length) and are barely visible to the naked eye. The Lewis spider mite undergoes one larval and two nymphal stages before becoming an adult. Mobile mites are green to a yellowish. Under a hand lens, multiple dark blotches can be seen on each side of the adult mite's body. Eyes appear as two red eyespots. Lewis spider mite eggs are laid on the undersides of leaves and are spherical, clear, and colorless when laid but become pearly white as hatch approaches. Lewis spider mite colonies often first appear near leaf edges or veins. Eggs emerge about 3 days after they are laid, and the lifecycle from egg to adult emergence occurs in about 14 days, at 77°F. Development time takes longer at lower temperatures.

Lewis spider mite has a wide host range, including ornamentals such as poinsettia and roses. It can also be found on weeds, such as castor bean, in and around the field. With the onset of warm weather, these mites migrate to the foliage of the plant and begin to lay eggs. In the mild winter coastal growing regions of California, it is unusual for a large percentage of mites to become dormant; instead they continue to grow and lay eggs, although at a slower pace during the winter months than in summer. The Lewis spider mite undergoes one larval and two nymphal stages before becoming an adult. The life cycle, under ideal conditions of hot and dry weather, can take place in 10 days.

### DAMAGE

Spider mites, including the Lewis spider mite, feed on plant juices and cause a yellow stippling on the leaf surface. As the number of mites grows and feeding progresses, leaves turn yellowish brown before drying up and falling off. Feeding by Lewis spider mites on fruiting strawberries reduces plant vigor and fruit yield and size.

### MANAGEMENT

The key to successful management of Lewis spider mites is to monitor their numbers and to initiate insecticide applications in a timely manner. Once mite numbers are high, damage has already occurred, and the mite numbers are difficult to control.

#### Biological Control

The most effective biological control agent of Lewis spider mite are the predatory mites *Neoseiulus californicus*, *N. fallacis*, and *Amblyseius andersoni*, which are introduced species. *N. californicus* does best in temperatures of 50° to 91°F, so it is compatible with both spider mite and strawberry plant development. Although they occur naturally in California strawberry production areas, they may be purchased and released in fields for additional control.

It is best to release predatory mites during cool mornings and avoid releasing them during high dry winds. Release the predatory mites early in the season, before spider mite populations build up. Apply predatory mites at the rate of 10,000 to 20,000 per acre in conventional fields and 40,000 or more per acre in organic fields.

*Phytoseiulus persimilis* is not an effective predator of Lewis spider mite.

#### Cultural Control

Roguing (removing) heavily infested plants can reduce mite numbers. Controlling dust by watering or oiling surrounding roads and planting dust control barriers helps to reduce Lewis spider mite numbers.

#### Organically Acceptable Methods

Use cultural and biological controls including the release of predatory mites, and narrow range oil sprays, such as Organic JMS Stylet oil, on organic strawberries.

#### Monitoring and Treatment Decisions

Learn to differentiate between Lewis and twospotted spider mites, since the control strategies for the two mites are different. No precise treatment thresholds have been established for Lewis spider mites in strawberries. Monitor to keep track of increasing pest mite numbers as well as predatory mite numbers to determine the risk that populations will continue to grow. A ratio of 1 predator to 10 Lewis spider mites is considered favorable for biological control. Good under-leaf coverage is essential when applying acaricides. This is especially important with non-residual products such as the spray oils, since mites that escape contact with the spray will survive.

Common name (Example trade name)	Amount/Acre	REI+ (hours)	PHI+ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

- A. HORTICULTURAL OIL#  
(Organic JMS Stylet Oil) 3 qt 4 0  
MODE OF ACTION: Contact including smothering and barrier effects.  
COMMENTS: Amount is for 100 gal/acre; may use up to 150 gal/acre water carrier. Spray with ground equipment for optimum coverage of leaf surfaces. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Heed label warnings about compatibility with other pesticides.
- B. BIFENAZATE  
(Acramite 50WS) 0.75–1 lb 12 1  
MODE-OF-ACTION GROUP NUMBER<sup>1</sup>: 20D  
COMMENTS: Use permitted on bearing and non-bearing crops. PHI is for bearing canes. Use minimum of 50 gal water/acre.
- C. HEXYTHIAZOX  
(Savey 50 DF) 4–6 oz 12 3  
MODE-OF-ACTION GROUP NUMBER<sup>1</sup>: 10A  
COMMENTS: Do not make more than one application per year.
- D. ABAMECTIN\*  
(Agri-mek SC) 3.5 fl oz 12 3  
MODE-OF-ACTION GROUP NUMBER<sup>1</sup>: 6  
COMMENTS: Toxic to predatory mites and relatively toxic to parasites, but fairly safe for general predators.
- E. CYFLUMETOFEN  
(Nealta) 13.7 fl oz 12 1  
MODE-OF-ACTION GROUP NUMBER<sup>1</sup>: 25A  
COMMENTS: For resistance management, do not make more than one Nealta application before rotating to a miticide with a different mode of action.
- F. NEEM OIL#  
(Trilogy) 1–2 gal/100 gal water 4 0  
MODE OF ACTION: Unknown. A botanical insecticide.  
COMMENTS: Apply with sufficient water carrier to provide complete coverage. Most effective when applied before mites and eggs are present in large numbers. Repeat applications on 7- to 21-day intervals until mite numbers and damage reach acceptable levels. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield.
- G. AZADIRACTIN#  
(Neemix 4.5) Label rates 4 0  
MODE-OF-ACTION GROUP NUMBER<sup>1</sup>: un  
COMMENTS: An insect growth regulator.
- H. COTTONSEED/CLOVE/GARLIC OILS#  
(GC-Mite) 1 gal/100 gal water 0 0

COMMENTS: Good coverage is essential for control; the use of a spreader/sticker may improve contact and efficacy of treatment. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Apply no more than once in a 7-day period.

- I. CINNAMALDEHYDE  
 (Cinnacure A3005) 1-2 gal 4 0  
 MODE OF ACTION: A botanical miticide.  
 COMMENTS: Apply in 100 to 200 gal water/acre, apply every 10 days and check for phytotoxicity.

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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 development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

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

NA Not applicable.

# LYGUS BUG (WESTERN TARNISHED PLANT BUG) (7/18)

**Scientific Name:** *Lygus hesperus*

## DESCRIPTION OF THE PEST

Western tarnished plant bug, which is commonly referred to as lygus bug, is a serious pest in Central Coast and Oxnard strawberry-growing areas where strawberries are typically grown past May and through the summer months, but they rarely become a pest in Southern California and the Central Valley where fresh market berry harvest is generally complete by the end of June. However, lygus bug is an occasional problem in these areas on second-year plantings and berries held through the summer.

Adults are about 0.25 inch (6 mm) long, oval, and rather flattened. They are greenish or brownish and have reddish-brown markings on their wings. In the center of their back is a distinct, but small, yellow or pale green triangle that helps distinguish them from other insects. The immature forms are pale green and look similar to an aphid. They can be distinguished from aphids by their more rapid movements.

Nymphs of the third and later instars are green and characterized by five black dots on the back—two on the segment immediately behind the head, two on the next segment, and one in the middle of the abdomen. A similar nonpest species that may be confused with lygus bug, *Calocoris*, frequently is found when monitoring weed and legume crop hosts for lygus bug. *Calocoris* has two prominent black dots on the back, just behind the head, and dark wing tips. Lygus bug adults have no black dots on the back. Both nymphs and adults of *Calocoris* are longer and narrower than lygus bug.

False chinch bug (*Nysius* spp.), an occasional minor strawberry pest that migrates into strawberry fields from weedy hosts, can also be confused with lygus bug. However, false chinch bug adults are smaller [0.1–0.2 inch (2.5–5 mm)], and grayish brown with a slender body. They have silvery gray wings that lack a cuneus (small triangle on the apical area of the forewings, typical of lygus bugs) and have four to five parallel veins on the membranous part, while lygus bug has closed cells (veins that loop and don't go to the end of the wing) on the membranous part of the wing. Nymphs are brownish gray with orange or reddish markings, and the front of the head (when viewed from above) is more triangular and pointed than lygus bug. There are no management guidelines for this pest except for good weed management.

## DAMAGE

Lygus bugs are one of the causes of irregularly shaped, cat-faced strawberries; another cause may be poor pollination, which results in small undeveloped seeds. Lygus bugs damage fruit by puncturing individual seeds; this, in turn, stops development of the berry in the area surrounding the feeding site. Straw-colored seeds that are large and hollow are a good indication of lygus bug damage. Lygus bug damage is more of a problem in strawberry-growing areas where continuous fruit production occurs.

## MANAGEMENT

To successfully manage lygus bug

- Control weed hosts in winter.
- Monitor for the appearance of lygus bug nymphs on weed hosts and adults on strawberries in spring.
- Time insecticide sprays to control lygus bug nymphs before they cause significant damage. Sprays must be timed to kill the earliest instars of nymphs because registered insecticides are not very effective on adults.

It is important to limit the number of treatments for lygus bug, because most of the insecticides that are effective against lygus bug disrupt natural enemies of spider mites. Control actions for lygus bug in strawberries generally are needed only in growing areas of the Central Coast and Oxnard, and the management activities described below apply to these areas. Once flower development begins in Central Valley strawberries, you can watch for the appearance of lygus bug adults during other routine monitoring activities.

### Biological Control

*Anaphes iole* is a naturally occurring parasitic wasp. It can be found in strawberry fields and surrounding lygus bug habitat, but because thresholds for this pest are very low, economically acceptable results are not achieved. A nymphal parasitoid, *Peristenus relictus*, is also found in some strawberry production areas.

Naturally occurring predators that feed on the nymphal stages of lygus bug include bigeyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), minute pirate bugs (*Orius tristicolor*), and several species of spiders.

## Cultural Control

Controlling weeds along roadways, ditches, and field borders near strawberry fields to help prevent spring buildup of lygus bug numbers is fundamental to lygus bug management in strawberries. Overwintered lygus bugs lay eggs in weeds in January that hatch in March. Carry out weed control measures in March and early April while lygus bugs are still nymphs. Once adults are present on weeds, they will migrate into strawberries when the weeds dry or are removed. Spraying adults or weeds to prevent movement is not very effective. To avoid adult migration in spring, mow or disc under cover crops, especially legumes, before they flower and while lygus bugs are still in the nymphal stages.

One cultural approach is to grow flowering plants in or adjacent to fields to attract lygus bug adults, but this approach requires careful monitoring and management to prevent an even greater problem from occurring. Adult lygus bug will lay eggs on the flowering plants, and nymphs will emerge from late March through April. The nymphs must be controlled at this time before they become adults and move to the strawberry plantation. Destroying the plants by discing or mowing is the most effective method of removing the infested, flowering plants. It is also possible to apply insecticides registered for use on strawberries for control of nymphs; however, none of the registered insecticides will provide complete control of the nymphs. If the plants are allowed to flower later into the season, carefully monitor the plants for the presence of lygus bug nymphs and take appropriate actions to prevent their movement into strawberries. This approach generally targets local populations of lygus bug and does not adequately impact longer-range lygus bug migration from drying foothill weeds.

Some growers have used suction devices (bug-vacs) to control lygus bug for many years. Research has shown that an efficient bug-vac can reduce adult numbers by 75% and nymphs 9 to 50%, but efficiency can vary considerably depending on the machine. Consistent vacuuming 1 to 2 times weekly can manage low to moderate numbers of lygus bug. If lygus bug numbers are moderate to high, use of vacuum machines alone will not reduce damage to the acceptable level. In the absence of effective fungicide programs, vacuums may increase problems with powdery mildew and gray mold by spreading the pathogens that cause these diseases. Additionally, they may remove a large portion of the general predator population.

## Organically Acceptable Methods

Use biological and cultural controls and insecticidal soap sprays on organically certified strawberries.

## Monitoring and Treatment Decisions

In February, monitor for the first appearance of lygus bug nymphs on plant hosts around the field to determine when these plants should be destroyed and to establish the first biofix for the degree-day model. Important plants and the key times to monitor them are outlined in the following table:

Important Plant Hosts of Lygus Bugs				
Common name (scientific name)	Time of Year			
	Feb.	Mar.	Apr.	May
California burclover ( <i>Medicago polymorpha</i> )			I	I
California poppy ( <i>Eschscholzia</i> spp.)			I	I
chickweed ( <i>Stellaria media</i> )	I	L		
common groundsel ( <i>Senecio vulgaris</i> )			L	L
curly dock ( <i>Rumex crispus</i> )				L
filaree ( <i>Erodium</i> spp.)	I	I	I	I
lambsquarters ( <i>Chenopodium album</i> )				I
little mallow (cheeseweed) ( <i>Malva parviflora</i> )				L
lupines ( <i>Lupinus</i> spp.)			L	L
milk thistle ( <i>Silybum marianum</i> )			I	L
mustards ( <i>Brassica</i> spp.)	I	I	L	L
pineapple-weed ( <i>Chamomilla suaveolens</i> )			L	

redmaids ( <i>Calandrinia ciliata</i> )		L		
shepherd's purse ( <i>Capsella bursa-pastoris</i> )		L		
wild radish ( <i>Raphanus raphanistrum</i> )	L	L	L	L

I = lygus bug present L = lygus bug present in higher numbers

Begin monitoring the strawberry plants in mid-April to detect when adults first appear in the field. Establishing when adults first enter the field also serves as the biofix for part of the degree-day model described later. Continue monitoring the field regularly after this time to establish whether or not lygus bug densities are economically important and exceed the treatment threshold. Record your results (*example survey form*).

Threshold levels for lygus bugs depend on the monitoring method used.

- When a beat sheet (12-inch embroidery hoop with muslin or other device of similar size) is used:
  - Divide the field into blocks and sample four 200-foot lengths of row in each block.
  - Sample one plant every 20 feet of row by placing the beating tray under the plant and beating it with your hand.
  - Apply sprays when one lygus nymph is found in 20 plants sampled.
- Continue weekly monitoring as long as fruit are being harvested for fresh market or freezer pack.

Currently registered insecticides are most effective against young first- and second-instar nymphs. Insecticides applied to later nymphal stages and adults are not very effective. Adult lygus that are not killed by sprays may migrate from the field to nearby weeds when pesticides are applied but can return.

Calculating degree-days (DD) is an effective way of determining the time of egg hatch, which occurs just before the best treatment times for lygus nymphs. This information can greatly improve the timing of lygus sprays and weed abatement in central coast areas, where damage from lygus is an annual problem.

Accumulate degree-days for lygus bug using a lower threshold of 54°F. There are two primary periods when lygus migrate from weeds into strawberries. Use degree-days to determine when peak egg hatch occurs following each migration.

- The first migration is by the overwintered adults; it usually occurs in April. Not all fields will have damaging levels of lygus at this time.
- If treatment thresholds are exceeded, apply the first spray 252 degree-days from the date you find the first adult in the field after April. This will generally be from late May to early June.
- The second treatment period is at 799 degree-days (late June–early July) from the date the first nymphs are found in weeds (typically in March) and targets nymphs from the second migration of lygus bugs into strawberry fields.
- A third treatment period corresponds to the emergence of nymphs that come from both adults that have established in the field and those that have migrated to strawberries during the summer; it is about 799 degree-days (early August) after the first spray.

To learn more about how to use degree-days to time insecticide applications, see *Using Degree-Days to Time Insecticide Applications in Fruit and Nut Orchards*. For assistance in calculating degree-days for lygus bug in your location, see *Degree-days: Lygus Bug in Strawberries*.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. FENPROPATHRIN* (Danitol 2.4 EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A	10.67 fl oz	24	2



Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<p>COMMENTS: Synthetic pyrethroids are the most effective pesticides currently registered for lygus control in strawberries. However, very high levels of resistance to this pesticide have been identified in some growing areas. Therefore, although this pesticide can suppress spider mites, it should be used primarily to control lygus. Use of this pesticide is limited to two applications per year, but to reduce the pressure for resistance development, make no more than two applications of all pyrethroids to the crop each year. To delay resistance and to avoid the severe spider mite outbreaks that result from application of pyrethroids, it is preferable to target the summer generation of lygus in areas where fruit is produced throughout the summer. See label for harvest restrictions. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.</p>			
B. BIFENTHRIN* (Brigade WSB) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A	Label rates	12	0
<p>COMMENTS: Synthetic pyrethroids are the most effective pesticides currently registered for lygus control in strawberries. However, very high levels of resistance to this pesticide have been identified in some growing areas. Therefore, although this pesticide can suppress spider mites, it should be used primarily to control lygus. Use of this pesticide is limited to two applications per year, but to reduce the pressure for resistance development, make no more than two applications of all pyrethroids to the crop each year. To delay resistance and to avoid the severe spider mite outbreaks that result from application of pyrethroids, it is preferable to target the summer generation of lygus in areas where fruit is produced throughout the summer. See label for harvest restrictions. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.</p>			
C. FLONICAMID (Beleaf 50SG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 9C	2.8 oz	12	0
<p>COMMENTS: Apply when lygus bug first appear, before high numbers appear. For resistance management, do not apply more than two sequential applications without first rotating to an insecticide with a different mode of action.</p>			
D. FLUPYRADIFURONE (Sivanto 200SL) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4D	14 fl oz	12	0
E. NOVALURON (Rimon 0.83EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 15	12 fl oz	12	1
<p>COMMENTS: Apply when adults are first observed in the field. Target initial application prior to egg hatch.</p>			
F. NALED (Dibrom 8E) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B	1 pt	48	1
<p>... PLUS ...</p>			
THIAMETHOXAM (Actara) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A	4 oz	12	3
<p>COMMENTS: Do not apply Dibrom when temperatures over 90°F. 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 active ingredient. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.</p>			
G. ACETAMIPRID (Assail 70WP) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A	1.7–3 oz	12	1
<p>COMMENTS: Gives better control of nymphs than adults. Can be tank mixed with fenpropathrin (Danitol) or bifenthrin (Brigade); however, to delay the development of insecticide resistance by lygus, aphids, and whiteflies, (especially where imidacloprid [Admire] is used), this tank mix should be reserved for situations where acetamiprid is not effective by itself. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum active ingredient on any label when tank mixing products that contain the same active ingredient. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.</p>			
H. THIAMETHOXAM (Actara) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A	4 oz	12	3

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<p>COMMENTS: Gives better control of nymphs than adults. Can be tank mixed with fenpropathrin (Danitol) or bifenthrin (Brigade); however, to delay the development of insecticide resistance by lygus, aphids, and whiteflies, (especially where imidacloprid [Admire] is used), this tank mix should be reserved for situations where thiamethoxam is not effective by itself. 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 active ingredient. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.</p>			
I. NALED (Dibrom 8EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Do not use when temperature exceeds 90°F. Because naled is an organophosphate like malathion, it is not effective in some growing areas because of resistance. Do not apply more than 5 pt/acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1 pt	48	1
J. MALATHION (Malathion 8E) (Malathion 5EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Only effective against first three nymphal instars. Very high levels of resistance to this pesticide have been identified in some growing areas. Check the California Strawberry Commission pink sheets for annual information on this. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.5–2 pt 1.5–3 pt	12 12	3 3

**ORGANIC OPTIONS** (Efficacy research may be lacking on these products)

A. AZADIRACHTIN# (Neemix 4.5, AzaGuard) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.	Label rates	4	0
B. <i>ISARIA FUMOSOROSEA</i> # (PFR-97 20% WDG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : —	Label rates	4	0
C. <i>BEAUVERIA BASSIANA</i> # (BotaniGard ES) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : —	Label rates	4	0

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## ROOT BEETLES (7/18)

**Scientific Names:** Black vine weevil: *Otiorhynchus sulcatus*  
 Cribrate weevil: *Otiorhynchus cribricollis*  
 Fuller rose beetle: *Pantomorus cervinus*  
 Woods weevil: *Nemocestes incomptus*  
 Hoplia beetle: *Hoplia dispar*, *H. callipyge*

### DESCRIPTION OF THE PESTS

Root beetles are occasional problems on California strawberries primarily in nonfumigated and/or second-year plantings in the San Joaquin Valley. They feed at night and hide around the crowns of plants during the day and, with the exception of adult hoplia beetles, they cannot fly. The adults, nearly all females, emerge in late spring or summer, feed on strawberry foliage, and lay their eggs around the crowns about 1 month after emergence. After hatching, the larvae work their way into the soil and feed on strawberry roots and crowns through the fall.

Root weevil larvae have curved, white or pink bodies that are about 0.38 inch (9.7 mm) long when fully grown. They have distinct brown heads and no legs. In spring, they resume feeding and can cause extensive damage before they pupate. Root weevils have a single generation each year.

The Fuller rose beetle, also called Fuller rose weevil, can be distinguished from the other weevils by an oblique, white band on the side of each wing cover. In addition, their larvae have pale, almost white heads. The black vine weevil is the largest and has a distinct black color. The woods weevil is the smallest of the group.

Hoplia are scarab beetles that are brown and 0.40 inches (10 mm) long. They are primarily a problem in San Joaquin Valley plantations that have not been fumigated. In the San Joaquin Valley, adults emerge in mid-April and are active for about 1 month. They are attracted to strawberry flowers and fruits, where they feed on petals and young, green fruit. Eggs are laid on the soil or on strawberry crowns; the resulting larvae enter the soil to feed on roots and are found associated with the roots from fall through spring. The larvae are 0.45 inches (11 mm) long and characteristically C-shaped. They feed for 2 years before pupating.

### DAMAGE

Larvae of all of these beetles feed on the roots of strawberry plants and can completely devour small rootlets and destroy the bark and cortex of larger roots. Soon after feeding begins, plants wilt because the roots can no longer provide moisture for leaves. Hoplia larvae will severely stunt and eventually kill infested plants. It is not uncommon to find beetle larvae that have penetrated into the lower portion of the plant's crown.

Adult weevils feed on foliage and remove large scallops from the leaves. Such leaf damage is a good indication that weevils are present but is not economically damaging to the plants. Adult hoplia beetles feed on flower petals, but it is not known if their feeding injures young fruit.

### MANAGEMENT

The rapid removal of plantings following harvest and preplant fumigation destroy beetle larvae and pupae in the soil. Soil solarization may be effective for hoplia beetles in the Central Valley. The use of sudangrass as a cover crop may serve to increase beetle numbers in the field.

#### Biological Control

Parasitic nematodes that target immature insects in the soil are available commercially. However, preliminary research did not show success using them for control of beetle larvae infesting strawberry roots.

#### Cultural Control

Annual plantings reduce the likelihood of high numbers of beetles building up in fields. Rotating to a nonhost crop (such as lettuce or cole crops) will further reduce beetle numbers in the soil.

#### Organically Acceptable Methods

Use cultural controls, especially annual plantings, soil solarization for hoplia beetles, and crop rotation on organically certified strawberries.

## Monitoring and Treatment Decisions

Even one hoplia grub in the crown or roots will cause significant damage. If plants wilt or appear stunted or reddish, larvae may be present. Examine roots to determine if root weevil larvae are present, because cold temperatures can also induce reddening. Dig several plants and look for C-shaped grubs in the crown or roots.

Soil fumigation for weed and disease control will destroy larvae and pupae in the soil, and root weevils and hoplia beetle do not appear to become problems in fumigated fields. In nonfumigated fields, chemigation can be effective.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

### PREPLANT FUMIGATION

*Note: Fumigants such as 1,3-dichloropropene, chloropicrin, and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.*

#### A. SEQUENTIAL APPLICATION

*First, apply one of the following:*

- |   |                  |           |   |
|---|------------------|-----------|---|
| • 1,3-DICHLOROPROPENE* <sup>S</sup> /CHLOROPICRIN* <sup>S</sup><br>(Telone C35)   | Label rates      | See label | 0 |
| (InLine)  | 28–33 gal (drip) | See label | 0 |
| MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : —/8B   |                  |           |   |
| COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb.  |                  |           |   |
| ... or ...  |                  |           |   |
| • 1,3-DICHLOROPROPENE* <sup>S</sup><br>(Telone II)  | 9–12 gal (shank) | See label | 0 |
| COMMENTS: Liquid that diffuses as a gas through soil. Effective against nematodes and insects. Rates vary with soil texture and efficacy strongly affected by soil moisture and temperature. One gallon of product weighs 10.1 lb.  |                  |           |   |
| ... or ...  |                  |           |   |
| • CHLOROPICRIN* <sup>S</sup><br>(Tri-Clor EC)   | Label rates      | See label | 0 |
| MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 8B   |                  |           |   |
| COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation, the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb. |                  |           |   |

*Then, 5 to 7 days later apply one of the following:*

- |   |             |           |   |
|---|-------------|-----------|---|
| • METAM SODIUM* <sup>S</sup><br>(Vapam HL, Sectagon 42)   | 37.5–75 gal | See label | 0 |
| COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.   |             |           |   |
| • METAM POTASSIUM* <sup>S</sup><br>(K-Pam HL)   | 30–60 gal   | See label | 0 |
| COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium. |             |           |   |

### CHEMIGATION

- |   |             |             |   |
|---|-------------|-------------|---|
| A. DIAZINON*<br>(Diazinon 50W)                | Label rates | 72 (3 days) | 5 |
| MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B |             |             |   |

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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COMMENTS: Liquid diazinon applied through the drip irrigation system can be fairly effective, and a second application can give almost 100% control. Highly toxic to bees.

- ‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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 insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.
- § Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

# SALTMARSH CATERPILLAR (7/18)

**Scientific Name:** *Estigmene acrea*

## DESCRIPTION OF THE PEST

Adult moths are white with orange abdomens and black spots on their wings. Unlike females, the hind wings of male moths are orange. Larvae, or caterpillars, are black with many tufts of long orange, black, and white hairs, and tend to curl up in a ball when disturbed. Very young caterpillars feed in a large, gregarious mass for the first two to three instars before dispersing. Mature caterpillars are almost 2 inches long.

Overwintering mature caterpillars pupate in spring. Emerging moths lay their round, shiny eggs in several rows forming a neat cluster on the undersides of leaves. There are several generations each year.

## DAMAGE

When saltmarsh caterpillars first hatch, they remain clustered and feed on the undersides of the leaves where the eggs were laid. They skeletonize the foliage of plants adjacent to the egg mass. As caterpillars grow and disperse, they eat small holes (0.25–0.4 inch [6–10 mm] diameter) in the leaves. This type of damage is generally of little or no concern, but the caterpillars can also make superficial bites in the fruit, causing losses.

## MANAGEMENT

Biological control generally keeps saltmarsh caterpillar numbers low. If late summer populations develop, a spot treatment may adequately control these caterpillars.

### Biological Control

Young larvae have a high mortality rate, perhaps from a naturally occurring virus, which helps to limit caterpillar numbers. There are also several natural enemies, including parasitic wasps and flies that help to control this pest.

### Cultural Control

Caterpillars migrating from adjacent fields or uncultivated areas can be stopped by physical barriers such as a plowed ditch, a ditch of water, or a slipperly, vertical aluminum foil fence several inches tall.

### Organically Acceptable Methods

Use cultural and biological controls and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad on organically certified strawberries.

### Treatment Decisions

Sprays are best applied while the young caterpillars are still in the gregarious, skeletonizing phase. They are most susceptible to *Bacillus thuringiensis* at this time. Because populations are localized, spot treatments are recommended.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. SPINOSAD (Entrust)# (Success)	1.25–2 oz 4–6 fl oz	4 4	1 1
MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5			
COMMENTS: Most effective against younger larvae. Rotate to an insecticide with a different mode of action after two successive applications. Maintaining proper pH of the spray tank water is critical for maximum efficacy. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
B. <i>BACILLUS THURINGIENSIS</i> ssp. <i>KURSTAKI</i> # (various products)	Label rates	4	0
MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 11A			
COMMENTS: Use when loopers are in the 1st or 2nd instar. Apply to plants when they are dry.			

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
C. METHOXYFENOZIDE (Intrepid 2F) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 18	6–12 fl oz	4	3

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

# SLUGS (7/18)

**Scientific Names:** Garden slug: *Arion hortensis*  
Gray garden slug: *Deroceras reticulatum*

## DESCRIPTION OF THE PESTS

Slugs have no shell, are slimy and have bodies that are flexible in shape. They move by gliding along on a muscular "foot." This muscle constantly secretes mucus, which later dries to form the silvery slime trail that signals the presence of these pests. Slugs can be found on the plant at night and in the early morning, and under the plastic or other mulch during the day. They are sensitive to dryness, and will seek out moisture, making the humid environment under the mulch of strawberries attractive to them.

The garden slug is larger than the gray garden slug. It measures about 1 to 1.5 inch in length and is gray to dark brown. Living for about one year, the garden slug is sexually mature in about 3 weeks. This slug is sensitive to cold and many will not survive a cold winter.

The gray garden slug is mottled gray and about 0.5 to 0.75 inch (12–19 mm) long. It takes from 3 to 4 months for the gray garden slug to reach maturity. This slug is less sensitive to cold than the garden slug and is better able to survive mild winters in high numbers.

Peak egg-laying for both slugs occurs from late September through early November. Most eggs deposited before late October hatch during fall; those deposited in November hatch from late February through spring.

## DAMAGE

Slugs feed on ripe fruit and produce rough holes that render the fruit unmarketable. These holes may be invaded by secondary pests such as sowbugs, earwigs, and small beetles. Slugs also feed on the leaves of strawberries, and the effects of the rasping feeding are ragged holes in the leaves.

## MANAGEMENT

Cleaning up debris in fields to make them less hospitable to slugs can help prevent large numbers of slugs from developing. If damaging numbers of slugs are present, baits can be applied.

### Cultural Control

The elimination of hiding places such as rocks, weeds, logs and boards will assist in reducing the numbers of slugs, because of the removal of habitat. Furthermore, growers can seek to plant away from areas with lots of debris, such as leaves and ground covers.

### Organically Acceptable Methods

Use cultural controls and Sluggo bait on organically certified strawberries.

### Treatment Decisions

Apply baits during fall and spring when slugs are most mobile on the ground surface in search of food and mates. Adverse weather conditions keep the slugs, especially the juveniles, inactive and they do not consume enough bait. The efficacy of metaldehyde baits may also be reduced by cool, wet weather because slugs produce less mucus during these periods.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. METALDEHYDE (Deadline M-PS)	10–25 lb	12	0
COMMENTS: Use higher rate for heavy infestation. This bait has minimal impact on other organisms in the field. Avoid contacting the fruit with bait.			



Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
B. IRON PHOSPHATE# (Sluggo G)	20–44 lb	0	0
COMMENTS: Apply using standard fertilizer granular spreader. If ground is dry, wet it before applying bait. Reapply as bait is consumed or at least every 2 weeks.			

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

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

# Acceptable for use on organically grown produce.

## SPIDER MITES (7/18)

**Scientific Names:** Twospotted spider mite: *Tetranychus urticae*  
 Carmine spider mite: *Tetranychus cinnabarinus*  
 Strawberry spider mite: *Tetranychus turkestanii*

### DESCRIPTION OF THE PESTS

#### Twospotted spider mite

Twospotted spider mite eggs are about 0.006 inch (0.14 mm) in diameter and are laid on the undersides of leaves. They are spherical, clear, and colorless when laid but become pearly white as hatch approaches.

Nymphs, adult males, and reproductive adult females are oval and generally yellow or greenish. There are one or more dark spots on each side of their bodies, and the top of the abdomen is free of spots.

Adult female twospotted spider mites may stop reproduction during the coldest winter months in production areas of colder inland valleys. Diapause is indicated by a change in color to bright orange. In coastal growing areas it is rare to have a significant proportion of the population undergo diapause. Mating and egg laying typically occur year-round in all coastal strawberry-growing regions.

#### Carmine spider mite

Carmine spider mite, a close relative of the twospotted spider mite, is bright red. It is commonly found at low densities in Southern California, Central Coast, and San Joaquin Valley growing regions. Carmine mite numbers usually decline as temperatures warm in spring.

#### Strawberry spider mite

Both strawberry and twospotted spider mites look similar; they can only be distinguished by the morphological characters of male genitalia. Twospotted spider mite is the predominant species in strawberries grown on the Central Coast. Strawberry spider mite occurs in some of these areas, with mixed populations of both twospotted and strawberry spider mites seen particularly during the warmer parts of the production season.

### DAMAGE

Twospotted spider mite and carmine spider mite damage appears as stippling, scarring, and bronzing of the leaves and calyx. Twospotted spider mite feeding is particularly damaging during the first 2 to 5 months following transplanting in late summer or fall. Mite feeding during this critical period of plant growth substantially reduces berry number per plant and overall plantation yield. Yield loss is detectable at all mite infestation levels exceeding one mite per leaflet.

Plants are less sensitive to mite feeding after initial berry set.

- Substantial yield loss results from 15 to 20 mites per mid-tier leaflet after berry set.
- Plants that sustain infestations greater than 75 mites per leaflet may become severely weakened and appear stunted, dry, and turn red.

The highest numbers of twospotted mites are often observed following the peak spring fruit harvest. This peak is typically followed by a rapid, natural decline in mite numbers when the plant enters a vegetative growth cycle. Twospotted mite numbers may again increase later in summer as fruit production by day-neutral cultivars again increases.

### MANAGEMENT

- Cultural practices such as vernalization of transplants that favor vigorous plants are key to minimizing damage from spider mites.
- Protect natural enemies as much as possible by choosing insecticides and miticides that are least harmful to natural enemies.
- If necessary, supplement natural enemies by releasing predatory mites.
- When treating for mites, choose the most selective miticide and alternate it with a miticide of a different chemistry or mode of action to avoid the development of resistance.

#### Biological Control

Predator mites commercially available for release:

- *Phytoseiulus persimilis*
- *Neoseiulus (Amblyseius) californicus*
- *Neoseiulus fallacis*
- *Galendromus occidentalis*

Of the commercially available predatory mites, only the first three are commonly used for spider mite suppression, most frequently *Phytoseiulus persimilis*. *P. persimilis* is an aggressive feeder, multiplies and spreads rapidly, and is a specialist predator that feeds exclusively on pest mites. However, in the absence of these pest mites, *P. persimilis* feeds on its own species, causing the population to gradually disappear.

#### **Predatory mite releases**

1. Monitor fields on a regular basis to determine spider mite numbers.
2. Applying a short-residual miticide to reduce spider mite numbers before a predator release may improve biological control under some conditions.
3. Make predatory mite releases early in the season before spider mite numbers begin to increase or following winter spider mite treatments intended to reduce overwintering mites. On the Central Coast, spider mites are first observed typically in January or February, while further south spider mite infestations may first develop in fall.
4. Following predator mite release, monitor spider mite numbers closely to evaluate the effectiveness of the predatory mites in maintaining the pest mites below economically injurious levels.

If low spider mite numbers are present in localized areas, make spot releases. Although research is lacking, experience suggests the following release rates:

- When pest numbers are low:
  - Release of an average of two to three predators per plant.
  - For more widespread infestations early in the season when spider mite numbers are low: make releases of about 30,000 per acre (about 1.5 predatory mite per plant) either as a single, large release or as three smaller releases of 10,000 per acre, depending on severity of weather conditions and spider mite numbers in the field.
- When the pest mite numbers are at threshold level:
  - Release an average of five predators per plant.
  - Once mite numbers increase to threshold levels, inundative releases may reduce twospotted spider mite infestations, but these must be made at release rates exceeding 100,000 per acre because once spider mite numbers begin to increase, it is difficult for predators to reduce their numbers below economic thresholds.

Insecticides, miticides, and certain fungicides that are not selective will kill the predators. Make releases only after residues are below lethal levels following any pesticide application.

*Phytoseiulus persimilis* has become established in most coastal strawberry-growing areas, and naturally occurring populations often move into spider mite-infested fields on their own. *Neoseiulus (Amblyseius) californicus* has also been found to naturally infest strawberry plantations in some growing areas and can effectively maintain spider mite populations that are below threshold levels. Another predator mite, *Phytoseiulus macropilus*, occasionally occurs in strawberries early in spring.

Other natural enemies of mites include minute pirate bug (*Orius tristicolor*), a small, black lady beetle (spider mite destroyer, *Stethorus* spp.), a small, black rove beetle (*Oligota oviformis*), bigeyed bugs (*Geocoris* spp.), brown lacewings (*Hemerobius* spp.), green lacewings (*Chrysopa* spp.), sixspotted thrips (*Scolothrips sexmaculatus*), damsel bugs (*Nabis* spp.), and a predaceous midge larvae (*Feltiella acarivora*).

#### **Cultural Control**

Strawberry cultivars vary in susceptibility to twospotted spider mite infestation and tolerance of twospotted spider mite feeding. When transplanted in fall, short-day cultivars are generally less tolerant of mite feeding than day-neutral cultivars, particularly later in the fruit-production season. When transplanted in summer, short-day cultivars are relatively tolerant of mite feeding.

Preplant chilling (vernalization) directly promotes plant vigor. Fall transplant, nursery location, preharvest chilling, nursery harvest date, and length of pretransplant supplemental cold storage can all affect a plant's

vernalization. Plants with low amounts of chilling have low vigor and can develop intolerable mite infestations. Excessive chilling promotes increased vigor and reduces mite abundance, but other production factors are adversely affected (i.e., delayed flowering, large plant size, and increased vegetative runner production at the expense of flowering and fruiting). Be sure transplants have received adequate chilling for the variety and area and receive proper irrigation and fertilization.

Other controllable factors that can be used to promote plant vigor are

- soil preparation and fumigation,
- use of polyethylene plastic mulch, and
- proper irrigation to prevent water stress.

Road dust control is also important in inhibiting mite infestations.

Cultivars and cultural practices vary between production regions. Obtain information on cultivars and cultural practices pertinent to a particular growing region from your University of California County Cooperative Extension office or from transplant nurseries before making planting decisions.

### Organically Acceptable Methods

Use cultural and biological controls, including releases of predatory mites, sprays containing plant-derived oils or organic stilet oil, and bioinsecticides such as *Beauveria bassiana*, *Burkholderia* sp. strain A396, or *Chromobacterium subtsugae* strain PRAA4-1 on organically certified strawberries.

### Miticide Resistance

Twospotted spider mites have a history of rapidly developing resistance to miticides when a miticide is repeatedly applied to the same population.

- Alternate miticides that have different modes of action to reduce development of resistance to a specific miticide.
- Spray based on sampling, to avoid unnecessary pesticide applications. Spray only infested portions of the field, if applicable.
- Organophosphate, carbamate, and pyrethroid insecticide applications can induce twospotted spider mite outbreaks. If possible, avoid early season insecticide applications or apply insecticides that are less disruptive to beneficial arthropods. Careful selection and use of insecticides early in the season can potentially reduce the number of miticide applications.

### Monitoring and Treatment Decisions

Vigorous plant growth during the first 4 months following fall transplant is a key factor in successful strawberry production. Monitor mid-tier leaves during this critical period when mite feeding is extremely damaging.

1. Randomly select 10 leaflets per acre in small fields and 5 leaflets per acre in larger fields. When using a mite-brushing machine, the leaves from each acre can be brushed as one sample.
2. Examine the undersurface of mid-tier leaflets with a hand lens to count the number of mites or use a mite-brushing machine.
3. Record your observations on a sampling form.

The established economic threshold for this period is an average of five mites per mid-tier leaflet. Summer transplants have a higher threshold of an average of 10 mites per mid-tier leaflet during this same period. Once harvest begins, strawberries become more tolerant of mite feeding and treatment thresholds increase to an average of 15 to 20 mites per mid-tier leaflet. Treatment thresholds may vary somewhat depending on location, time of season, cultivar, overall plant vigor, yield potential, and the availability of an effective miticide.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
A. CYFLUMETOFEN (Nealta) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 25A COMMENTS: For resistance management, do not make more than one Nealta application before using an effective miticide with a different mode of action.	13.7 fl oz	12	1
B. ACEQUINOCYL (Kanemite 15 SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 20B COMMENTS: Do not use less than 100 gal water/acre and do not apply more than twice per year. Allow a minimum of 21 days between treatments. Crops other than strawberries may not be rotated for at least 1 year following treatment.	21–31 fl oz	12	1
C. SPIROMESIFEN (Oberon 25C) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 23 COMMENTS: Do not make more than two applications per crop season.	12–16 fl oz	12	3
D. ETOXAZOLE (Zeal Miticide) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 10B COMMENTS: A mite growth regulator that is most effective against eggs and immatures. Most effective when applied before high numbers develop, but it will eventually control even high numbers of mites. Effective against both twospotted and carmine spider mites but not against cyclamen mite. Do not apply more than 3 oz/acre per season.	2–3 oz	12	1
E. FENPYROXIMATE (FujiMite 5SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 21A COMMENTS: FujiMite provides an alternative mode of action to manage development of resistance in mites. Although it is a contact material, it is effective on all developmental stages of mites. It is active on all important mite species including: two-spotted spider mite, Lewis mite, and cyclamen mite. FujiMite is toxic to predatory mites but is non-toxic to most other natural enemies. Spray coverage is key in obtaining maximum results.	2 pt	12	1
F. BIFENAZATE (Acramite 50WS) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 20D COMMENTS: Do not make more than one application per harvested crop. Two sprays may be made per year if more than one crop is harvested each year; minimum period between applications is 21 days. A good resistance management strategy is to use bifenazate as the winter spray (if needed) and as a rotational pesticide with abamectin and hexythiazox during the season. It has low toxicity to predatory mites and predatory insects. Bifenazate can be used once per year in strawberry nurseries. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	0.75–1 lb	12	1
G. HEXYTHIAZOX (Savey 50DF) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 10A COMMENTS: Limited to one application per season. Follow label directions for last date this pesticide can be applied because this varies by region. Most effective against eggs and nymphs, so best used when mites begin to actively reproduce. Not registered for nurseries.	6 oz	12	3
H. ABAMECTIN* (Agri-Mek 0.15EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 6 COMMENTS: Abamectin is less effective under cold weather conditions than in warm weather because movement into the leaf does not readily occur. Abamectin is most effective when used in paired applications 7 to 10 days apart when mites reach detectable levels under warmer temperatures in late winter and spring. Repeat the paired applications if necessary to maintain twospotted spider mite control. Do not exceed 16 fluid oz/acre per application or 64 fl oz/acre (four applications) in a growing season. Do not apply in less than 100 gal water/acre (200 gal/acre is optimal). Do not repeat treatment within 21 days of second application. Abamectin is not registered for strawberry nurseries. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	16 fl oz	12	3
I. NARROW RANGE OIL#			

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
(Omni Oil 6-E) MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Acceptable for use on organically grown crops only when fruit are not present. Apply in 60 gal water/acre with air-assist, low-volume ground equipment or 200 gal water/acre with standard ground spray equipment. Use this miticide for low-to-moderate spider mite numbers; higher levels of mite infestation require treatment with more effective miticides. Make applications only during winter months when plants are semi-dormant to reduce the risk of phytotoxicity. Do not use oil from peak bloom through fruiting period or when air temperatures are expected to exceed 75°F within several days following application. Do not apply from Jan. 16 to May 30 in Orange and San Diego counties or the Oxnard Plains; do not apply from Feb. 1 to Jun. 15 in the Santa Maria Valley; and do not apply from Mar. 1 to Jun. 30 in Monterey and Santa Cruz counties.	1–2%	12	0
J. NEEM OIL# (Trilogy)	1–2 gal/100 gal water	4	0
MODE OF ACTION: Unknown. A botanical insecticide. COMMENTS: Apply with sufficient water carrier to provide complete coverage. Most effective when applied before mites and eggs are present in large numbers. Repeat applications on 7- to 21-day intervals until mite pest pressure is over. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield.			
K. COTTONSEED/CLOVE/GARLIC OILS# (GC-Mite)	1 gal/100 gal water	0	0
COMMENTS: Good coverage is essential for control; the use of a spreader/sticker may improve contact and efficacy of treatment. Oil sprays need to be applied frequently to achieve acceptable control, however, frequent applications of oils can damage the plant and compromise fruit yield. Apply no more than once in a 7-day period.			
L. ROSEMARY/PEPPERMINT OILS# (Ecotec)	1–4 pt	0	0
MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Danger of phytotoxicity is greater when used at higher rates and when temperatures are warm. Do not apply in less than 50 gal water/acre. No residual activity, so repeat applications at 10-day intervals while mite numbers are increasing.			
M. STYLET OIL (Organic JMS Stylet Oil)# (JMS Stylet Oil)	72 fl oz in 75 gal	4	0
MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. There is a danger of phytotoxicity when oils are applied incorrectly, especially under conditions of high temperature and low humidity; not recommended for use in Southern California. Use of ceramic spray nozzles is recommended by the manufacturer. Make applications at a minimum pressure of 400 psi. Lower pressures lead to larger droplet sizes, increasing the potential for phytotoxicity. Only organic JMS Stylet oil is acceptable for use on organically certified produce.			
N. BURKHOLDERIA sp. STRAIN A396# (Venerate)	Label rates	4	0
O. CHROMOBACTERIUM SUBTSUGAE STRAIN PRAA4-1# (Grandevo)	Label rates	4	0
P. BEAUVERIA BASSIANA# (Mycotrol ESO, BotaniGard ES)	Label rates	4	0

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

# Acceptable for use on organically grown produce.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## SPOTTED-WING DROSOPHILA (7/18)

**Scientific Name:** *Drosophila suzukii*

### DESCRIPTION OF THE PESTS

(View male/female identification card)

Spotted-wing drosophila is found in many California counties infesting ripening cherry, raspberry, blackberry, blueberry, and strawberry fruits; it has also been observed attacking other potential hosts such as grape, peach, boysenberry, varieties of Japanese plums, plumcots and other soft-fleshed fruits. Adults and maggots closely resemble the common vinegar fly, *Drosophila melanogaster*, and other *Drosophila* species that primarily attack rotting or fermenting fruit. The spotted-wing drosophila, however, readily attacks undamaged fruit.

Adults are 0.08 to 0.12 inch (2–3 mm) flies with red eyes and a pale brown thorax and abdomen with black stripes on the abdomen. The most distinguishable trait of the adult is that the males have a black spot towards the tip of each wing. The female does not have spots on its wings, but their ovipositor (egg-laying organ) is very large and serrated, unlike other common *Drosophila* species. Larvae are small [up to 0.14 inch (3.5 mm)], white cylindrical maggots that are found feeding in fruit. One to many larvae may be found feeding within a single fruit. After maturing, the larvae partially or completely exit the fruit to pupate.

Like other vinegar flies, spotted-wing drosophila appears to have a short life cycle (one to several weeks depending on temperature) and may have as many as ten generations per year. This rapid developmental rate allows it to quickly develop large numbers and inflict severe damage to a crop.

In Japan and in coastal California the adult flies may be captured throughout much of the year. They are most active at 68°F; activity decreases at temperatures above 86°F, and egg laying stops at about 91°F. In California, it appears to overwinter in vegetation surrounding agricultural fields in the wintertime, and then reinvades in very low numbers once fruit are apparent again in the spring.

### DAMAGE

Unlike other vinegar flies that occur in California, spotted-wing drosophila attacks healthy ripening fruit as well as damaged or rotting fruit. The female's serrated ovipositor is strong and able to penetrate the skin of soft-skinned fruit and lay eggs just under the skin, creating a small depression ("sting") on the fruit surface. Each clutch of eggs is from one to three, and the female deposits eggs on many fruits. Multiples of larvae within a single fruit are quite possible because many females may visit the same fruit to lay eggs. As fruit integrity is compromised by spotted-wing drosophila's activities, common vinegar flies (i.e., *Drosophila melanogaster*) may also lay eggs in the damaged fruit.

Eggs hatch and the maggots develop and feed inside the fruit, causing the flesh of the fruit to turn brown and soft; sunken areas that exude fluid often appear on the fruit surface. Damage can provide an entry site for infection by secondary fungal and bacterial pathogens, but this is not always the case.

### MANAGEMENT

Spotted-wing drosophila may be monitored with a variety of traps. In the berry production districts of the Central Coast of California, one of the most successful trapping methods has been a yeast-sugar-water mix in a jar or bottle trap. Beyond the capability to consistently trap spotted-wing drosophila, this mix is sufficiently clear to easily distinguish the flies, and it can be used for several weeks without changing the liquid.

To make the bait solution:

1. Mix 12 oz of water with 0.25 oz of baker's yeast (e.g., Fleischmann's) and 4 teaspoons of sugar.
2. Allow the solution to ferment for a day or so (in an open or loose-lidded container, as quite a bit of gas is formed during the fermentation process).
3. Transfer 3 to 4 fl oz of the liquid to a 500-ml Nalgene bottle or other container of low height that has four or more 7/16-inch diameter holes drilled into the lid. (The idea is to use a container that is low enough that the opening is well below the plant canopy.) Flies enter the bottle through these holes and while there is the possibility of flies escaping back out through the holes, most eventually land in the liquid and drown.



While some jars or bottles can be hung with a wire in the shady, cooler areas of the field or farm, others should be placed directly in the strawberry field itself. It is important that the traps be placed in the shady canopies of the strawberry plants. Check traps at least weekly and count and remove the flies.

A successful management program will focus on reducing breeding sites and controlling flies before they lay eggs because to date, there are no effective tools for controlling maggots within fruit. The fruit seems most susceptible to attack after it has colored and developed some sugar.

### Sanitation

Infested fruit that remains in the field or orchard serves as a food source and allows eggs and larvae to fully develop and serves as a source of more flies. When feasible, removing ripe, overripe, and rotten fruit from the crop site and destroying, either by burial or disposal in a closed container can help to reduce the numbers of this pest. This can be especially important if a nearby susceptible crop will soon be ripening.

### Harvest Intervals

Even though spotted-wing drosophila lays eggs in newly ripening fruit, they readily infest older, overripe fruit as well. Extending harvest intervals, as may occur for the processing crop, will result in larger numbers of spotted-wing drosophila, more fruit damage, and a greater risk for future infestations of the new crop.

### Pesticides

If monitoring indicates pest presence, apply a spray to protect the fruit. If monitoring indicates high numbers of spotted-wing drosophila early in the season, an earlier spray to lower numbers may be warranted in addition to harvest applications.

Pesticides such as malathion, pyrethroids, and spinosyns have been shown to be very effective in reducing numbers of spotted-wing drosophila, but they are seldom needed in California strawberries unless many flies are present. Fruit tend to be at risk primarily when sanitation is lax and over-ripe fruit are present or because of extended harvest intervals. Horticultural oils do not show much promise as a control agent.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

A. MALATHION (Malathion 8) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Highly toxic to honey bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.5–2 pt	12	3
B. SPINOSAD (Entrust SC#, Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Do not apply more than 18 fl oz/acre per calendar year. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	4–6 fl oz	4	1
C. BIFENTHRIN* (Brigade WSB) MODE OF ACTION: 3A COMMENTS: Highly toxic to honey bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	8–32 oz	12	See label

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

# Acceptable for use on organically grown produce.

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI† (days)
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<sup>1</sup> Rotate insecticides 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 development of resistance. For example, the organophosphates have a Group number of 1B; insecticides with a 1B Group number should be alternated with insecticides that have a Group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

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

## VINEGAR FLY (7/18)

**Scientific Names:** *Drosophila melanogaster* and other species

### DESCRIPTION OF THE PESTS

Vinegar flies, also known as fruit or pomace flies, are small, yellowish flies that are commonly attracted to fermenting fruit of all kinds. Vinegar fly numbers may increase as the freezer harvest season progresses and temperatures become warmer, especially in Southern California. The 0.15 inch (4 mm) larva can be found in very ripe cull and damaged fruit in the fields. Adults lay 700 to 800 eggs in a life span that ranges from 7 to 8 days in summer to 20 to 30 days at other times. Ideal temperatures for development of this insect are in the low 80°F (27° to 30°C). The flies do not lay eggs at temperatures below 54°F (12°C) or above 91°F (33°C).

### DAMAGE

Vinegar flies are primarily a problem in strawberries picked for freezing. Because this fruit is allowed to ripen in the field to allow easy removal of the calyx and core of the strawberry during picking, the harvest interval is increased and the fruit becomes more susceptible to infestation. Vinegar flies are attracted to very ripe or damaged fruit in the field where they lay their eggs. Eggs and larvae are primarily a contamination problem.

### MANAGEMENT

When conditions favor an increase in vinegar fly numbers, remove as much overripe fruit from the field as possible, or bury it, and follow good sanitation practices in areas around the field. Monitor vinegar flies with bait traps to help detect infestations as early as possible.

#### Cultural Control

- Limit fruit fly breeding sites.
- Completely remove ripe fruit from the plants.
- When possible, shorten harvest intervals as temperatures increase.
- Practice good sanitation in and around the field. Identify and clean up external sources of flies (e.g., cull piles of strawberries or other rotting fruit and nearby citrus groves where old fruit may be on the ground).

#### Organically Acceptable Methods

Use cultural controls, especially field sanitation, and pyrethrin sprays on organically certified strawberries.

#### Monitoring and Treatment Decisions

Although no monitoring or treatment guidelines exist for vinegar flies in strawberries, adult flies may also be monitored using fermented fruit traps consisting of a container filled with overripe fruit covered with an inverted funnel. High numbers of vinegar flies are found in May and June in Southern California, so start checking for flies at the end of April in these areas. It may be possible to spray portions of fields or obvious sources of flies with pyrethrins to control adult flies.

Vinegar fly eggs and larvae in the berries cannot be killed using insecticides. Apply sprays to target adult flies. Adult flies are most active in the early morning and late afternoon; this is also the time they will have greater exposure to an insecticide application. Best time to apply insecticide for adults is between 8 and 11 a.m. and between 5 and 7 p.m.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. MALATHION (Malathion 5EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B	1.5–3 pt	12	3

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
COMMENTS: Provides effective control. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
B. PYRETHRIN# (PyGanic 1.4EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A COMMENTS: Apply in sufficient water for thorough coverage. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	16–64 fl oz	12	0
C. PYRETHRIN/PIPERONYL BUTOXIDE (Pyrenone Crop Spray) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A/— COMMENTS: Variable efficacy. Not as disruptive of natural enemies as other options.	Label rates	12	0

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

# Acceptable for use on organically grown produce.

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## WESTERN FLOWER THRIPS (7/18)

**Scientific Name:** *Frankliniella occidentalis*

### DESCRIPTION OF THE PEST

Western flower thrips are slender, about 0.03 inch (0.8 mm) long insects when mature. Adults have feathery wings and vary from yellow to dark brown. Nymphs are white or yellowish with small dark eyes. In spring, there is an increase in the number of flower thrips on alfalfa, weeds, ice plant, and other vegetation and move from these hosts when they are cut, stop flowering, or dry up.

Strawberry plantations often have a mixed population of thrips that includes a low percentage of the onion thrips, *Thrips tabaci*.

### DAMAGE

Thrips feeding on strawberry blossoms cause the stigmas and anthers to turn brown and wither prematurely, but not before fertilization has occurred. Although often numerous on berries when cat-facing occurs, western flower thrips do not cause cat-facing, which is a result of lygus bug feeding and possibly other factors. As fruit develops, thrips feeding may cause a russetting (Type I bronzing) of the fruit around the cap, but this injury is seldom economic. (Other types of bronzing are associated with phytotoxicity from sulfur and other types of sprays (Type II) and from plant physiological factors (Type III). The most severe bronzing that covers the entire fruit is believed to have a physiological cause that is associated with hot temperatures occurring from May through July.

### MANAGEMENT

Western flower thrips thrive and increase their numbers on many crops and weeds. They may migrate into strawberries when other crops are harvested, when second-year strawberries or other perennial hosts stop flowering, or when weeds dry up in spring. Control is usually not necessary because western flower thrips rarely cause economic damage at densities that typically occur in strawberry fields. Sprays applied to control thrips disrupt biological control of other pests such as twospotted spider mites, lygus bugs, whiteflies, and other insects. If an insecticide is necessary, choose the least disruptive insecticide to preserve biological controls agents.

#### Biological Control

Naturally occurring minute pirate bugs (*Orius* spp.) feed on thrips. *Orius* are also available commercially, but release rates and timing have not been determined.

#### Organically Acceptable Methods

Use sprays of the Entrust formulation of spinosad, azadirachtin (Neemix), *Isaria fumosorosea* (PFR-97), *Beauveria bassiana* (Botanigard), or combinations of these products on organically certified strawberries.

#### Monitoring and Treatment Decisions

Consider spraying only if 10 thrips per blossom are found when flowers are shaken onto a flat dark-colored surface and thrips are counted. A better way to sample thrips is to place randomly collected flower blossoms into a glass container with several drops of either ethyl acetate or methyl isobutyl ketone (or with a small amount of either of these chemicals soaked into cotton or other absorbent material). After at least one-half hour, count the thrips by removing the blossoms and shaking them onto black paper. Because more thrips will be found with this method, the treatment threshold is greater than that indicated for shaking flowers.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following 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. Always read the label of the product being used.*

*(For increased efficacy, IRAC group 5 or 1B can be tank mixed with insecticides containing pyrethrins (group 3A). For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum rate of active ingredient on any label when tank mixing products that contain the same active ingredient.)*

A. SPINOSAD

Common name (Example trade name)	Amount per acre	REI# (hours)	PHI# (days)
(Entrust)# (Success) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Rotate to an insecticide with a different mode of action after two successive applications. Can be toxic to some natural enemies (e.g. predatory mites, syrphid fly larvae) when sprayed and shortly thereafter (8–24 hours). Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.25–2 oz 4–6 fl oz	4 4	1 1
B. SPINETORAM (Radiant SC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 5 COMMENTS: Rotate to an insecticide with a different mode of action after two successive applications of either spinetoram or spinosad to help delay the development of resistance to group 5 insecticides. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	6–10 fl oz	4	1
C. MALATHION (Malathion 5EC) (Malathion 8E) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Residual activity only about 1 week. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1.5–3 pt 1.5–2 pt	12 12	3 3
D. NALED (Dibrom 8EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Do not use when temperature exceeds 85°F. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	1 pt	48	1
E. ACETAMIPRID (Assail 70WP) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	0.8–1.7 oz	12	1
F. <i>BEAUVERIA BASSIANA</i> # (BotaniGard ES) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : – ...PLUS... AZADIRACTIN# (AzaGuard) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.	Label rates	4	0
G. <i>ISARIA FUMOSOROSEA</i> # (PFR-97 20% WDG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : – ...PLUS... AZADIRACTIN# (Neemix 4.5) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.	Label rates	4	0
H. PYRETHRIN/PIPERONYL BUTOXIDE (Pyrenone) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A/ – COMMENTS: Variable efficacy. Not as disruptive of natural enemies as some other options.	Label rates	12	0
I. PYRETHRIN# (PyGanic 1.4EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A COMMENTS: Apply in sufficient water for thorough coverage. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	16–64 oz	12	0

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI‡ (days)
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- † Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.
- Information not available.
- # Acceptable for use on organically grown produce.
- <sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their website at <http://irac-online.org/>.

## WHITEFLIES (7/18)

**Scientific Names:** Greenhouse whitefly: *Trialeurodes vaporariorum*  
 Iris whitefly: *Aleyrodes spiroeoides*  
 Strawberry whitefly: *Trialeurodes packardi*

### DESCRIPTION OF THE PESTS

Iris whiteflies and, to a lesser extent, strawberry whiteflies have always been present in low numbers in strawberry fields in California. These species are usually kept below damaging levels by their natural enemies. In recent years, however, a third species, the greenhouse whitefly, has become a major pest in certain areas on the Central Coast and in Southern California. The greenhouse whitefly has a large host range including avocados, beans, blackberries and other berries, cucumbers, eggplants, lettuce, melons, peas, peppers, tomatoes, and many ornamentals, and these alternate hosts serve as sources for whiteflies that enter strawberry fields.

Whiteflies go through six stages in their development: eggs; first, second, third, and fourth instar immatures; and the adult. Eggs are microscopic and laid on the underside of leaves. Whiteflies do not have a true pupal stage, but the last part of the fourth instar, when the red eyes of the adult whitefly begin to appear, is often referred to as the "pupa." Only adults and the newly hatched nymphs (i.e., crawlers) are mobile. Greenhouse whiteflies numbers tend to increase in fall, reaching peak densities in late fall through winter in Central Coast plantings. In warm weather, whiteflies can complete a generation in as little as 18 days.

Whiteflies are easy to distinguish from other insect pests: adults of all species are about 0.04 inch (1 mm) in size with four membranous wings that are coated with white powdery wax. Whitefly species are most reliably distinguished from each other by examining the late fourth instar or red-eyed "pupal" stage.

#### Greenhouse whitefly

The greenhouse whitefly has long, waxy filaments around the margins in the "pupal" stage. When seen from the side, the greenhouse whitefly "pupae" are circular with flat tops, with the filaments emerging from the tops. Adult greenhouse whiteflies are solid white and hold their wings parallel (flat) to the top of the body.

#### Strawberry whitefly

Both adults and nymphs of the strawberry whitefly look similar to the greenhouse whitefly, but the strawberry whitefly nymphs never have the long filaments often found on the greenhouse whitefly "pupae."

#### Iris whitefly

Iris whitefly "pupae" also lack long filaments but have short waxy ones around their bodies. Iris whitefly adults hold their wings flat over their backs and have a dot on each wing.

### DAMAGE

Greenhouse whitefly can transmit viruses and is known to vector virus decline of strawberry in California. Whiteflies may reduce crop yields directly through their feeding on leaf sap, stunts plant growth, and decreases sugars in fruit. They also produce sticky honeydew that they excrete during feeding. The honeydew may cover plants and support the growth of black sooty mold fungus.

### MANAGEMENT

Successful management of greenhouse whiteflies requires an integrated program that focuses on prevention and relies on cultural and biological control methods when possible. Insecticides are often necessary if strawberries are grown so that continuous plantings are present in areas where greenhouse whiteflies have become established (summer plantings or second-year plantings adjacent to new plantings), if whitefly biological controls are disrupted by the use of a nonselective insecticide, or if adult whiteflies invade the strawberry plantations from adjacent crop hosts or from backyards. No precise treatment threshold has yet been developed for greenhouse whiteflies on strawberries, but even feeding at relatively low densities after transplanting can result in yield loss. Apply insecticides when honeydew, moderate to high numbers of whiteflies, or both are apparent during periods of warmer weather for summer- and fall-planted berries. Select insecticides carefully and use them only when monitoring indicates a need.

#### Biological Control

In most crops, greenhouse whiteflies and iris whiteflies are generally kept under control by naturally occurring parasitic wasps and general predators. Natural enemies of whiteflies include parasitic wasps of the genera



*Encarsia*, *Eretmocerus*, and *Prospaltella*, bigeyed bugs, pirate bugs, and lacewing larvae. In summer, in certain areas on the Central Coast and in Ventura County, 30 to 40% of greenhouse whiteflies are parasitized by native parasites.

*Encarsia formosa* is used worldwide for greenhouse whitefly suppression in greenhouses, but more research is necessary to determine if the release of this or other parasites can be helpful in preventing whiteflies from increasing in numbers in field situations.

### Cultural Control

For summer-planted strawberries, the practice of topping (cutting of old leaves, stems, runners, and old fruit spurs) in spring helps to reduce overwintering immature populations. Monitor whiteflies on adjacent hosts and initiate control there, if possible, before these crops are harvested to prevent the whiteflies from moving to strawberries. Minimizing dust by keeping field roads watered or oiled allows biological control to work effectively.

The source of infestation for new plantings on the Central Coast appears to be adjacent strawberry fields that are being maintained for a second year of berry production and summer plantings that have become infested from the previous season's fall plantings. It is important that berries held for a second year be monitored beyond the last day of harvest. If whiteflies are observed in the previous year's plantings once new fields are transplanted, the older plants need to be treated to protect new plantings in adjacent areas. Early pruning may be beneficial to reduce source populations. When berries are pruned it is important that the discarded plant material is removed from the field. It may not be economically feasible to maintain multiple-year plantings when severe infestations have been experienced the area.

### Organically Acceptable Methods

Preserve naturally occurring biological control agents, and use cultural controls, sprays of narrow range oil, azadirachtin (Neemix), *Isaria fumosorosea* (PFR-97), *Beauveria bassiana* (Botanigard), and insecticidal soaps on organically certified strawberries. Releases of *Encarsia formosa* into hot spots against low-to-moderate numbers of greenhouse whitefly are also acceptable for use on organic strawberries.

### Monitoring and Treatment Decisions

There are two monitoring methods for whiteflies: yellow sticky traps and leaf counts.

Sticky traps are useful for detection of whitefly infestation and determining relative infestation levels, but the number of whiteflies may not correlate closely with the number of immature whiteflies on leaves. Therefore, in addition to sticky trap counts, inspect strawberry foliage throughout the field on a weekly basis. Place one yellow sticky trap every ten acres and next to field edges to catch adult whiteflies as they move into the strawberry fields. Put the sticky cards vertically on stakes, just above the crop canopy. Count the number of adults trapped on each card weekly and record counts to track whitefly numbers. Replace sticky traps as necessary.

Monitor plants by counting the number of adults on 20 mid-tier leaflets in each quarter of a field and determine the average number. Also examine nymphs to determine what proportion of the nymphs are black, indicating they are parasitized.

When monitoring indicates that adult whitefly numbers are increasing rapidly and nymphs that are detected on leaves have no indication of parasitism (i.e., are not black), begin insecticide applications with products that control adult whiteflies. Insecticides (except imidacloprid), oils, and soaps are most effective against adults and early instar whiteflies but not against eggs. Very few insecticides are effective against the fourth instar "pupal stage." Try to time insecticide applications to when monitoring indicates that most of the population is in the adult and first-, second-, or third-instar stage.

If there is high risk of new plantings from nearby summer plantings or second-year fields that already have whiteflies, consider a preventive application of imidacloprid (Admire) at planting by injection into the planting hole or through the drip system. If application is through drip irrigation, it is best to preirrigate to make sure that the soil profile is well watered, then apply enough water to move the insecticide into the root zone. Imidacloprid (Admire) must be taken up by the plant to be effective.

Good coverage of the underside of leaves is essential for effective use of insecticides against whiteflies, but dosage applied is also important. When treating whiteflies, use lower volumes of water than would normally be used against pests like spider mites and drive the sprayer more slowly over the field if possible. An air-assist sprayer

might help. More than one application may be required for high numbers of whiteflies or if monitoring indicates that whitefly numbers are continuing to increase. Rotating between chemical classes when making multiple applications is recommended to reduce the development of resistance.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following 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. Always read the label of the product being used.</i>			
A. IMIDACLOPRID (Admire Pro, soil) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: A neonicotinoid insecticide. Best used as a preventive treatment. Can be applied through drip lines; see label for restrictions. When applying through drip, preirrigate so soil is moist. This insecticide must move into the root zone and be taken up by the plants to be effective, so sufficient water must be applied to promote its movement through the soil. Only apply once per year. Has a long residual activity; more moves into plant with each irrigation. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	10.5–14 fl oz	12	14
B. PYRIPROXYFEN (Esteem 0.86EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 7C COMMENTS: Apply after an application of imidacloprid (Admire) and when whitefly numbers just begin to increase. Control of adult whiteflies will take about 2 to 3 weeks following application, so apply before whitefly numbers increase significantly.	10 fl oz	12	2
C. FENPROPATHRIN* (Danitol 2.4EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 3A ...PLUS... MALATHION (Malathion 5EC) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 1B COMMENTS: Fenprothrin is a pyrethroid and malathion is an organophosphate. Use of fenprothrin is limited to two applications per year and multiple applications of pyrethroids can lead to resistance in target populations, so use the insecticide only when whitefly numbers warrant its use. Applications made early in the season can lead to severe mite outbreaks later on. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum active ingredient on any label when tank mixing products that contain the same active ingredient. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	10.66 fl oz  1.5–3.2 pt	24  12	2  3
D. THIAMETHOXAM (Actara) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : 4A COMMENTS: Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	3–4 oz	12	3

#### ORGANIC OPTIONS (Efficacy research may be lacking on these products)

A. AZADIRACHTIN# (AzaGuard, Neemix 4.5) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.	Label rates	4	0
B. ISARIA FUMOSOROSEA # (PFR-97 20% WDG) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : — ...PLUS... AZADIRACHTIN# (Neemix 4.5)	Label rates  Label rates	4  4	0  0

Common name (Example trade name)	Amount per acre	REI† (hours)	PHI‡ (days)
MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.			
C. <i>BEAUVERIA BASSIANA</i> # (BotaniGard ES) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : — ...PLUS... AZADIRACTIN# (AzaGuard) MODE-OF-ACTION GROUP NUMBER <sup>1</sup> : un COMMENTS: An insect growth regulator.	Label rates	4	0
D. NARROW RANGE OIL# (Omni Oil 6E) MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Apply in 60 gal water/ acre with air-assist, low-volume ground equipment or 200 gal water/acre. Moderately effective against low to moderate numbers when coverage is excellent. Make applications only during winter months when plants are semi-dormant to reduce the risk of phytotoxicity. Do not use oil from peak bloom through fruiting period or when air temperatures are expected to exceed 75°F within several days following application. Do not apply from Jan 16 to May 30 in Orange and San Diego counties or the Oxnard Plains; do not apply from Feb 1 to June 15 in the Santa Maria Valley, and do not apply from Mar 1 to Jun 30 in Monterey and Santa Cruz counties.	1–2%	12	0
E. INSECTICIDAL SOAP# (M-Pede) MODE OF ACTION: A contact insecticide with smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Do not exceed one application per month or two per season. Can burn plants, so apply only when temperatures are cool. Moderately effective against nymphs only. Requires excellent coverage.	1.25–2.5 oz/gal water	12	0

† Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.

# Acceptable for use on organically grown produce.

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

<sup>1</sup> Rotate insecticides 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; insecticides with a 1B group number should be alternated with insecticides 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 website at <http://irac-online.org/>.

## *Diseases*

(Section reviewed 7/18)

### **ANGULAR LEAF SPOT** (7/18)

**Pathogen:** *Xanthomonas fragariae*

#### **SYMPTOMS AND SIGNS**

Infection first appears as minute, water-soaked spots on the lower surface of leaves and calyxes. The lesions enlarge to form translucent, angular spots that are delineated by small veins and under conditions of high humidity will exude a viscous ooze of bacteria and bacterial exudates, which appears as a whitish and scaly film after drying. As the disease progresses, lesions coalesce and reddish-brown spots, which later become necrotic, appear on the upper surface of the leaves. A chlorotic halo usually surrounds the infected area.

#### **COMMENTS ON THE DISEASE**

This bacterium is not free-living in soil. It can, however, overwinter in soil on previously infected plant material. It is host-specific and highly resistant to degradation (i.e., it can persist on host plant debris in the soil for long periods of time). Lesions on the leaf surface serve as a source for secondary inoculum; cells are dispersed by splashing rain or overhead irrigation. The disease is favored by cool, moist days with cold nights near freezing.

*Xanthomonas fragariae* can cause vascular collapse, although this is uncommon in California. This symptom initially appears as a water-soaked area at the base of newly emerged leaves. Shortly after, the whole plant suddenly dies, much like plants infected with crown rot. *Xanthomonas fragariae* is also associated with strawberry blossom blight in California.

Angular leaf spot generally has a minor impact on fruit yields in California. However, it is a concern at strawberry nurseries, which may be subject to quarantine regulations for angular leaf spot on nursery stock for export.

#### **MANAGEMENT**

Angular leaf spot is kept to a minimum by using certified planting materials. Chemical controls are typically ineffective against this pathogen. Copper-containing compounds are registered but have caused phytotoxicity with repeated applications. Rotate crops to avoid infesting fields and avoid overhead irrigation when possible.

#### **Organically Acceptable Methods**

Use certified plants, use drip irrigation instead of overhead irrigation, and rotate crops in organically grown strawberries.

## ANTHRACNOSE (7/18)

**Pathogen:** *Colletotrichum acutatum*

### SYMPTOMS AND SIGNS

The most obvious symptoms of anthracnose in the field are petiole, runner, and fruit lesions. In some fields after planting, stunting and yellowing of plants may occur. Wilting and collapse of plants may occur, but this is less common in California annual plantings. Petiole and runner lesions or characteristic crown symptoms usually precede the collapse of affected plants. Diseased petioles and runners develop lesions that appear as dark brown or black, lens-shaped, sunken spots.

When crown tissue is infected and becomes decayed, the entire plant may wilt and die. Like *Phytophthora* crown rot, the internal crown tissue is discolored, but with anthracnose the discolored tissue is cinnamon to red in color whereas *Phytophthora*-rotted tissue is more of a chocolate brown; in addition, petiole and runner lesions are not produced by *Phytophthora* spp.

Fruit decay caused by anthracnose may be common in production areas depending on environmental conditions. If infected plants are present, decay can develop following periods of warm, rainy weather. Fruit at any stage of ripeness can be affected. Small, sunken, oval-to-round brown spots (on green fruit) or black spots (red fruit) develop and may expand to cover most or all of the fruit surface. Under high humidity, salmon or orange-colored spores can form on the lesions of the fruit, petioles, and runners. Decayed fruit tissue is firm and dry.

### COMMENTS ON THE DISEASE

*Colletotrichum acutatum* can survive in soil for at least 9 months without host plants. In addition to strawberry, several weeds are known to host this pathogen including chickweed, fiddleneck, and vetch. If strawberries are planted in infested soil, they become infected when soil containing spores is splashed onto crowns or stems by rain or irrigation water. In fields that have been fumigated, the disease usually originates on infected nursery stock or from volunteer strawberry plants in adjacent fields. In addition, inoculum can come from contaminated soil on field equipment or be introduced from nearby weeds.

### MANAGEMENT

Soil fumigation destroys most residual inoculum of *Colletotrichum* in the soil. In warm, inland fields soil solarization can be effective in destroying soil inoculum. Running water treatments can be used to wash soil from transplants. This reduces inoculum from infested transplants. Follow good sanitation procedures to prevent disease inoculum from entering the field, and rotate to nonhost crops where fumigation and solarization are not feasible. Fungicide dips can be used on transplants before planting in production fields. Foliar fungicides are available for use on plants when the disease is present and conditions are ideal for foliar and fruit disease development.

#### Clean Planting Stock

- Thoroughly wash all soil from plants before planting to reduce disease in crowns and fruit.
- Heat treatment of plants has been shown to reduce the amount of disease but can reduce the viability of some cultivars.

#### Cultural Control

- Use drip irrigation.
- Clean field equipment before using it in a field to ensure that contaminated soil and plant parts are not transported into a field or from an infested section of the field to a noninfested section.
- Clean equipment before leaving a contaminated field.
- Rotate with a nonhost crop to reduce levels of this pathogen in the soil.
- Practice good weed management in and around the field to destroy any weeds that may harbor the pathogen. Recent research has demonstrated the importance of removing the weeds from the fields after they are destroyed because the pathogen can still produce spores even though the weeds are dead.

#### Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30–45 days of hot weather that promotes soil temperatures of at least 122°F down to about 14 inches). The

effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

**Organically Acceptable Methods**

Use cultural controls, including soil solarization, and crop rotation, and wash soil from crowns before planting. Use annual plantings, as inoculum tends to readily build up in multi-year plantings; this disease tends to be much more severe in California in second-year fields.

**Monitoring and Treatment Decisions**

Good results in managing anthracnose have been obtained with a sequential application of chloropicrin or 1,3-dichloropropene plus chloropicrin followed 7 days later with metam sodium or metam potassium.

At planting, fungicide dips can be used on transplants before planting in fruit production fields.

During the growing season, watch for anthracnose symptoms during routine monitoring for spider mites and other pests. Because anthracnose and Botrytis should only occur following rainfall or sprinkler irrigation, they shouldn't be problems when the weather is dry. If moisture occurs, pay close attention to developing fruit. If fruit disease appears in a small area of the field or before the plant canopy is well developed, foliar fungicides may help prevent further spread of the disease and reduce crown infections. Thorough coverage of the fruit is important.

Be aware of developing fungicide resistance issues in some areas. Consult your local extension advisor. for more information.

For more information on the symptoms and management of anthracnose, see the *Anthracnose of Strawberry Production Guideline*.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

**PREPLANT FUMIGATION**

*Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.*

A. METHYL BROMIDE* <sup>S</sup> /CHLOROPICRIN* <sup>S</sup> (Tri-Con 50/50)	300–400 lb	See label	0
COMMENTS: Methyl bromide use is allowed <b>only in strawberry nurseries</b> through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.			
B. SEQUENTIAL APPLICATION <i>First, apply one of the following:</i>			
• 1,3-DICHLOROPROPENE* <sup>S</sup> /CHLOROPICRIN* <sup>S</sup> (Telone C35)	Label rates	See label	0
(InLine)	Label rates	See label	0
COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb. ... or ...			
• CHLOROPICRIN* <sup>S</sup> (Tri-Clor)	150–350 lb (shank)	See label	0
(Tri-Clor EC)	200–300 lb (drip)	See label	0

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.

*Then, 5-7 days after fumigation apply one of the following:*

- METAM SODIUM\*§  
(Vapam HL, Sectagon 42) 37.5–75 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  
... or ...
- METAM POTASSIUM\*§  
(K-Pam HL) 30–62 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.

**AT PLANTING**

- |    |  |                   |    |   |
|----|--|-------------------|----|---|
| A. | AZOXYSTROBIN<br>(Abound)   | 5–8 fl oz/100 gal | 4  | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11)   |                   |    |   |
|    | COMMENTS: Dip plants for 2 to 5 minutes and plant as quickly as possible. Most effective if transplants are washed to remove excess soil before dipping. Resistance to this fungicide has been reported. |                   |    |   |
| B. | CYPRODINIL/FLUDIOXONIL<br>(Switch 62.5WG)  | 5–8 oz/100 gal    | 12 | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Anilinopyrimidine (9) and Phenylpyrrole (12)   |                   |    |   |
|    | COMMENTS: Wash plants of excess soil prior to dipping. Dip plants for 2 to 5 minutes. Completely drain the transplants after dipping and plant as quickly as possible.                                   |                   |    |   |

**FOLIAR FUNGICIDES**

- |    |   |              |    |   |
|----|---|--------------|----|---|
| A. | CYPRODINIL/FLUDIOXONIL<br>(Switch 62.5WG)   | 11–14 oz     | 12 | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Anilinopyrimidine (9) and Phenylpyrrole (12)  |              |    |   |
|    | COMMENTS: Do not apply more than two consecutive applications. Do not exceed 56 oz of product/acre per year.  |              |    |   |
| B. | CAPTAN<br>(Captan 50WP)   | 3–6 lb       | 24 | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Multi-site contact (M4)   |              |    |   |
|    | COMMENTS: Do not apply in combination with, immediately before, or closely following oil sprays.  |              |    |   |
| C. | AZOXYSTROBIN<br>(Abound)  | 6–15.5 fl oz | 4  | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11)  |              |    |   |
|    | COMMENTS: Do not apply more than two consecutive foliar applications before switching to alternative chemistry. Do not apply more than 1 lb a.i./acre per season. |              |    |   |

\*\* Apply all pesticides in 200 gal water/acre to ensure adequate coverage.

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.



## BOTRYTIS FRUIT ROT (GRAY MOLD) (7/18)

**Pathogen:** *Botrytis cinerea*

### SYMPTOMS AND SIGNS

The fungus that causes Botrytis fruit rot, also known as gray mold, is widespread in the environment. It can infect strawberry flowers when spores landing on them and are exposed to free water during cool weather. Infections can either cause flowers to rot or Botrytis can become dormant in floral tissues. Dormant infections resume activity on the berry later in the season anytime before or after harvest when sugars increase and conditions become favorable to disease development.

Infections first appear as small brown lesions, often under the calyx. Lesions begin to sporulate within a day after resumption of growth, and sporulation appears under the calyx as a gray velvety mold. Lesion size increases rapidly. Both green and red berries are susceptible. Infected berries maintain their original shape and take on a velvety, gray-brown coat of spores. Initially, rotted areas are soft and mushy, becoming leathery and dry in the absence of high humidity. Millions of spores are produced on each berry and become airborne at the slightest touch or breeze.

Direct infection of the berries also occurs if berries are exposed to free water. These infections develop in the same manner as flower-infected berries but differ in that multiple initial lesions may appear anywhere on the berry's surface.

### COMMENTS ON THE DISEASE

During the growing season, the fungus is constantly present and is often found in new plantings. Nothing can be done to escape the presence of this fungus, but the level of inoculum in a particular field can be reduced by removing dead leaves and infected fruit. After harvest, the fungus survives in the soil as small, black, inactive sclerotia on tilled-in leaves and fruit. In addition, the fungus lives on decomposing, dead organic matter of many plant species in and around the growing area. Because wet, cool weather is necessary for development of this disease, it is mostly limited to the coastal growing regions and northern nurseries and causes very little damage in inland growing regions except during periods of unusually wet weather during fruit production.

### MANAGEMENT

Presently, control of Botrytis fruit rot ranges from repetitive fungicide treatments with no cultural control to intensive cultural methods with no fungicide applications. Environmental conditions in various microclimates play an important role in determining control strategies. Planting in areas where wind can rapidly dry out the plants and interrupt disease progress helps to reduce disease incidence.

#### Cultural Control

Remove and destroy dead or infected plant material to help reduce the amount of inoculum capable of producing new infections. Also, remove all ripe fruit during harvest as well as any fruit with signs of decay or rain damage. Growing strawberries in plastic tunnels has proven to effectively reduce the incidence of *Botrytis* infections. Using plastic mulches to prevent berry-soil contact also reduces disease except where water puddles under the fruit on the plastic.

Some cultivars have flowers and fruit that develop with an upright stature, which allows fruit to be exposed to better air movement and sunlight, and this reduces the risk of infection, but fruit tend to be more exposed to rain and hail. Fruit types with a "neck" or reflexed calyx (a calyx that grows away from the fruit) are less susceptible to the disease simply by eliminating or reducing primary infection sites.

#### Organically Acceptable Methods

- Select fields that are isolated from conventional growing areas and have environmental conditions that are not conducive to disease development (i.e., warm, dry spring weather or areas where wind is prevalent at some point during the day).
- Use varieties that are suited to the growing area with necked fruit or reflexed calyx.
- Remove all fruit after spring and summer rains and all plant residue after harvest, as sanitation is crucial for good control.

There are several organic fungicides available, but none have shown consistent efficacy against gray mold.

## Monitoring and Treatment Decisions

In areas without heavy coastal summer fog, inoculum levels may be low enough in clean fields that early sprays in spring can be omitted. In dry areas, leaf wetness seldom is of sufficient duration to cause epidemics, and some growers are finding it possible to grow strawberries without fungicides when strict sanitation practices are adhered to. In dense fog areas, inoculum density and environmental conditions conducive to disease development (i.e., cool, wet weather) should always determine when to apply fungicides. Because these conditions are usually seasonal, use a protective fungicide to prevent germination of spores when weather forecasts predict conditions ideal for disease development. Thereafter, set spray schedules according to disease pressure and environmental conditions.

No fungicide is recommended when conditions are not determined to be suitable for infection.

### Fungicide resistance

*Botrytis cinerea* has developed resistance to almost every mode of action chemistry, including pyraclostrobin/boscalid, fenhexamid, and iprodione.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

A. CYPRODINIL/FLUDIOXONIL (Switch 62.5WG) MODE-OF-ACTION GROUP NAME (NUMBER): Anilinopyrimidine (9) and Phenylpyrrole (12) COMMENTS: Begin applications at or before bloom and continue on a 7- to 10-day interval as long as conditions favor disease development. Do not plant rotational crops other than strawberries or onions for 30 days following last application and do not exceed 56 oz/ acre per year.	11–14 oz	12	0
B. PYRACLOSTROBIN/FLUXAPYROXAD (Merivon) MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11) and succinate dehydrogenase inhibitor (7)	8–11 fl oz	12	0
C. PYRACLOSTROBIN/BOSCALID (Pristine) MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11) and Carboxamide (7) COMMENTS: Begin applications at bloom and alternate with cyprodinil / fludioxonil (Switch) or fenhexamid (Elevate).	18.5–23 oz	12	0
D. PENTHIOPYRAD (Fontelis) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7)	16–24 fl oz	12	0
E. ISOFETAMID (Kenja) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7)	13.5–15.5 fl oz	12	0
F. FLUOPYRAM/TRIFLOXYSTROBIN (Luna Sensation) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7) and quinone outside inhibitor (11)	6–7.6 fl oz	12	0
G. FLUOPYRAM (Luna Privilege) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7)	6.84 fl oz	12	See label
H. CAPTAN (Captan 50WP) MODE-OF-ACTION GROUP NAME (NUMBER): Multi-site contact (M4)	3–6 lb	24	0

Common name (Example trade name)	Amount per acre**	REI† (hours)	PHI‡ (days)
COMMENTS: Can be tank mixed with fenhexamid (Elevate), thiram, or thiophanate-methyl (Topsin-M) for more effective control. 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 apply in combination with, immediately before, or closely following oil sprays. Do not apply more than 48 lb/year.			
I. THIRAM (Thiram Granuflo)	Label rates	24	3
MODE-OF-ACTION GROUP NAME (NUMBER): Multi-site contact (M3)			
COMMENTS: A carbamate (DMDC) fungicide. Good coverage of buds, blossoms, and fruits required for best results. Can be tank mixed with captan. 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.			
J. FENHEXAMID (Elevate 50WDG)	1.5 lb	12	0
MODE-OF-ACTION GROUP NAME (NUMBER): Hydroxyanilide (17)			
COMMENTS: Begin applications at early bloom before disease development begins; continue applications at 7- to 10-day intervals when conditions favor disease development but do not make more than two consecutive applications before alternating with a fungicide of a different chemistry for at least two applications. May be applied alone, or under light to moderate disease pressure it can be tank mixed at a rate of 1 to 1.5 lb/acre with a fungicide of a different chemistry (e.g. captan). 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 exceed 6 lb/acre per season.			
K. IPRDIONE (Rovral 4F)	1.5–2 pt	24	0
MODE-OF-ACTION GROUP NAME (NUMBER): Dicarboximide (2)			
COMMENTS: A dicarboximide fungicide. Do not make more than one application per season to reduce the likelihood of resistance development. Do not apply after first fruiting flower.			
L. THIOPHANATE-METHYL (Topsin-M)	0.75– 1.0 lb	24	1
MODE-OF-ACTION GROUP NAME (NUMBER): Methyl benzimidazole (1)			
COMMENTS: Tank mix with fungicide of different chemistry (e.g. captan) to reduce resistance problems. Do not apply more than 4 lb/acre per year. 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.			

\*\* Apply all pesticides in 200 gal water/acre to ensure adequate coverage.

† Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

## COMMON LEAF SPOT (7/18)

**Pathogen:** *Mycosphaerella fragariae* (anamorph=*Ramularia tulasnei*)  
(Reviewed 7/18; Updated 7/18)

### SYMPTOMS AND SIGNS

Common leaf spot first appears as small, deep purple spots on the upper surface of leaves. Spots enlarge to 0.125 to 0.25 inch (3–6 mm) in diameter with the center portion of the lesion turning brown then gray to white, depending on the age of the leaf and environmental conditions. Numerous spots may coalesce to kill the leaf.

On petioles, stolons, calyxes, and fruit trusses, elongated lesions may form and interfere with water transport in the plant, weaken the structure, or allow invasion by secondary organisms.

### COMMENTS ON THE DISEASE

Common leaf spot is one of the more important fungal leaf spot diseases of strawberry in California and is extremely common in areas with high rainfall. The pathogen is introduced into fruit production fields as small, black sclerotia on infected nursery material. Germination of sclerotia is initiated by fall and winter rains or sprinkler irrigation. Spores are dispersed by wind-driven rain.

### MANAGEMENT

Reducing inoculum on planting stock greatly reduces the likelihood of disease development.

#### Cultural Control

Use drip irrigation, remove infected leaves when practical, and be sure planting stock is clean. Choose a growing area with environmental conditions that are not conducive to disease development.

#### Organically Acceptable Methods

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

#### Treatment Decisions

Common leaf spot is a relatively minor disease on production strawberries in California; use fungicides only when monitoring indicates they are necessary.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.</i>			
A. CHLOROTHALONIL (Bravo Weather Stik) MODE-OF-ACTION GROUP NAME (NUMBER): Multi-site contact (M5) COMMENTS: May be used in nonbearing nurseries and as a preplant dip of transplants. Apply in nursery before disease establishment.	1.5 pt	12	NA
B. MYCLOBUTANIL (Rally 40W) MODE-OF-ACTION GROUP NAME (NUMBER): Demethylation inhibitor (3) COMMENTS: Apply in a minimum of 50 gal water/acre. Do not apply more than 30 oz/acre per year.	2.5–5 oz	24	0

\*\* Apply all pesticides in 200 gal water/acre to ensure adequate coverage.

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

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

NA Not applicable.

## FUSARIUM WILT (7/18)

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

### SYMPTOMS AND SIGNS

Symptoms of Fusarium wilt in strawberries consist of wilting of foliage, plant stunting, and drying and death of older leaves, while the youngest leaves in the center of the plant often remain green and alive. Symptoms usually first appear well after plants are established. Plants bearing heavy fruit loads or subjected to stress often show the most severe symptoms. Plants can eventually collapse and die completely. When internal tissues of plant crowns are examined, vascular and cortical tissues are dark to orange-brown. Internal tissues of the main roots are typically not discolored.

### COMMENTS ON THE DISEASE

Fusarium wilt is often most severe if the infected plant is subject to stresses due to weather extremes, deficiency or excess of water, poor soil conditions, or heavy fruit loads. Note that foliar dieback and internal crown discoloration symptoms are identical to those caused by *Macrophomina* crown rot. Therefore, confirmation of Fusarium wilt requires diagnostic procedures in a pathology lab. This soilborne fungus only attacks strawberry and will not cause disease on other crops. The fungus persists in the soil in the form of small survival structures called chlamydospores, which can last years in the soil in the absence of a host.

### MANAGEMENT

Select locations that do not have a history of Fusarium wilt. Preplant fumigation, which historically has been an important component of managing *Verticillium* wilt in strawberry fields, will also help control *Fusarium*. Fumigation will be most effective when crop residues have fully decomposed. Consequently, it is advisable to allow some time after incorporation before the fumigant is applied. Shank application of fumigants such as chloropicrin or chloropicrin plus 1,3 dichloropropene (Pic-Clor 60) applied at high rates under retentive film can control fungal pathogens, such *Fusarium* and *Macrophomina* (though only chloropicrin affects the fungus). Bed fumigation will not control pathogens in the untreated furrows.

Crop rotation with broccoli has been shown to help reduce *Verticillium* levels in the soil; the practice of crop rotation may also help manage *Fusarium*; it has not yet been thoroughly researched but is under current investigation.

#### Cultural Control

##### *Strawberry Cultivars*

Field tests have shown that cultivars such as Fronteras, Portola, and San Andreas are resistant to Fusarium wilt, whereas Albion and Monterey are susceptible. Additional research is being conducted to develop new resistant cultivars.

##### *Manage Stress*

Manage the strawberry crop so as to reduce stress on the plants. Irrigate the crop as appropriate for the stage of development, current evapotranspiration requirement, and soil moisture levels. Control pests, especially mites, which can exert significant stress on strawberry plants.

##### *Crop Rotation*

Rotating strawberries with broccoli can significantly reduce levels of the *Verticillium* pathogen in the soil. While not yet tested with *Fusarium*, crop rotations may also be useful.

#### Organically Acceptable Methods

Select fields that do not have a history of Fusarium wilt. Plant resistant cultivars. Rotate with any non-strawberry crop or with crops, which have the capacity to suppress the pathogen. Avoid stressing the plants.

#### Treatment Decisions

Drip fumigation of pre-plant fumigants may not effectively control soilborne pathogens in the entire bed; field research has demonstrated pathogen survival at the bed shoulders and in soil profiles deeper than 12 inches. Use of this application method should be considered carefully. Growers may improve fumigant distribution by using more than two drip lines per bed and by applying larger volumes of water to deliver the fumigants. Bed fumigation will not control these pathogens in the untreated furrows.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide’s properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

**PREPLANT FUMIGATION**

Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.

- A. METHYL BROMIDE\*§/CHLOROPICRIN\*§  
(Tri-Con 50/50) See label See label 0  
COMMENTS: Methyl bromide use is allowed **only in strawberry nurseries** through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.
- B. SEQUENTIAL APPLICATION  
*First, apply one of the following*
- 1,3-DICHLOROPROPENE\*§/CHLOROPICRIN\*§  
(Telone C35) Label rates See label 0  
(InLine) Label rates (drip) See label 0  
COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. According to state permit conditions, the maximum application rate of 1,3-dichloropropene is 332 pounds active ingredient per acre. One gallon of product weighs 11.2 lb.  
... or ...
  - CHLOROPICRIN\*§  
(Tri-Clor) 150–350 lb (shank) See label 0  
(Tri-Clor EC) 200–300 lb (drip) See label 0  
COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.  
... or ...
  - CHLOROPICRIN\*§/1,3 DICHLOROPROPENE\*§  
(Pic-Clor 60) 300–332 lb (shank) See label 0  
(Pic-Clor 60 EC) 200–300 lb See label 0  
COMMENTS: Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. According to state permit conditions, the maximum application rate of 1,3-dichloropropene is 332 pounds active ingredient per acre. Pic-Clor 60: One gallon of weighs 12.1 lb; Pic-Clor 60 EC: One gallon of weighs 11.8 lb.
- Then, 5-7 days after fumigation apply one of the following*
- METAM SODIUM\*§  
(Vapam HL, Sectagon 42) 37.5–75 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  
... or ...
  - METAM POTASSIUM\*§  
(K-Pam HL, Sectagon-K54) 30–62 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of K-Pam HL contains 5.8 lb of metam potassium; one gallon of Sectagon-K54 contains 5.63 lb of metam potassium.

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

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

NA Not applicable.

- <sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.
- § Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.
- ‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.



# LEATHER ROT (7/18)

**Pathogen:** *Phytophthora cactorum*

## SYMPTOMS AND SIGNS

All stages of fruit are susceptible to leather rot. Infected fruit develop diseased areas that are brown to shades of purple in color. The decay often expands throughout the fruit, resulting in a brown, leathery berry. The external infected area becomes tough while the internal tissue is somewhat softer. The central area of the fruit, if hollow, may contain the white mycelium of the pathogen, and the fruit tastes bitter.

## COMMENTS ON THE DISEASE

The leather rot pathogen requires splashing rain to transport the zoospores (motile spores) to the fruit, or in very wet conditions (i.e., flooding, standing water or pools of water on beds) the zoospores can swim to the plant.

## MANAGEMENT

Leather rot is not common on annual plantings of strawberries in California because it is usually controlled by preplant fumigation and plastic mulches. Cultural practices play an important role in disease prevention; soil solarization may also provide control. Plantings held for 2 or 3 years, however, could be infected by the leather rot pathogen.

### Cultural Control

Ensure that fields are prepared so that they have adequate water drainage. Remove diseased fruit and use plastic mulches. Avoid overhead irrigation; use drip irrigation. Straw mulch to prevent soil splashing has been effective in controlling this disease in the eastern United States.

### Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30-45 days of hot weather that promotes soil temperatures of at least 122°F). The effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

### Organically Acceptable Methods

Use field sanitation, good drainage, proper irrigation, soil solarization, and mulches in an organically certified crop.

### Treatment Decisions

If drip fumigation is planned, good results have been obtained with a sequential application of chloropicrin or 1,3-dichloropropene plus chloropicrin followed 7 days later with metam sodium or metam potassium. During the growing season, research data from the eastern United States indicate that mefenoxam (Ridomil Gold), fosetyl-aluminum (Aliette), and phosphorous acid (Fosphite) are effective in controlling this disease. Treat before the advent of splashing rains or very damp conditions.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

### PREPLANT

*Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.*

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
A. METHYL BROMIDE*§/CHLOROPICRIN*§ (Tri-Con 50/50)	300–400 lb	See label	0
COMMENTS: Methyl bromide use is allowed <b>only in strawberry nurseries</b> through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.			
B. SEQUENTIAL APPLICATION <i>First, apply one of the following</i>			
• 1,3-DICHLOROPROPENE*§/CHLOROPICRIN*§ (Telone C35)	Label rates	See label	0
(InLine)	Label rates (drip)	See label	0
COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb. ... or ...			
• CHLOROPICRIN*§ (Tri-Clor)	150–350 lb (shank)	See label	0
(Tri-Clor EC)	200–300 lb (drip)	See label	0
COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.			
<i>Followed 5-7 days after fumigation by one of the following</i>			
• METAM SODIUM*§ (Vapam HL, Sectagon 42)	37.5–75 gal	See label	0
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium. ... or ...			
• METAM POTASSIUM*§ (K-Pam HL)	30–62 gal	See label	0
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.			
C. FOSETYL-AL (Aliette WDG)	Label rates	12	0
MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33) COMMENTS: Apply as a preplant dip to strawberry roots and crowns for 15 to 30 minutes; plant within 24 hours after dipping.			

**GROWING SEASON**

A. FOSETYL-AL (Aliette WDG)	Label rates	12	0
MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33)			
B. MEFENOXAM (Ridomil Gold SL)	Label rates	48	0
MODE-OF-ACTION GROUP NAME (NUMBER): Phenylamide (4)			
C. PHOSPHOROUS ACID (Fosphite)	1–3 qt	4	0
MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33) COMMENTS: Do not apply with copper-based fungicides or fertilizers; allow 20 days after or 10 days before a copper treatment.			

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) 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.

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

## MACROPHOMINA CROWN ROT (7/18)

**Pathogen:** *Macrophomina phaseolina*

### SYMPTOMS AND SIGNS

Symptoms of *Macrophomina* crown rot in strawberries consist of wilting of foliage, plant stunting, and drying and death of older leaves, while the youngest leaves in the center of the plant often remain green and alive. Symptoms usually first appear well after plants are established and after plants begin bearing fruit or are subjected to stress. Plants can eventually collapse and die completely. When internal tissues of plant crowns are examined, vascular and cortical tissues are dark to orange brown. Internal tissues of the main roots may also be discolored and show the same dark brown coloration.

### COMMENTS ON THE DISEASE

*Macrophomina* crown rot, also known as charcoal rot, is most severe when the infected plant is subject to stresses due to weather extremes, water stress, poor soil conditions, or heavy fruit loads. Note that foliar dieback and internal crown discoloration symptoms are identical to those caused by *Fusarium* wilt. Therefore, confirmation of *Macrophomina* crown rot requires diagnostic procedures in a pathology lab. This is a soilborne fungus and persists in the soil in the form of small, black survival structures called microsclerotia. In California, research suggests that most of the isolates of *M. phaseolina* that infect strawberry have a narrow host range and only infect strawberry.

### MANAGEMENT

Select locations that do not have a history of *Macrophomina* crown rot. Preplant fumigation, which historically has been an important component of managing *Verticillium* wilt in strawberry fields, will also help control *Macrophomina* crown rot. Fumigation will be most effective when crop residues are fully decomposed or removed. Consequently, it is advisable to allow some time after incorporation before the fumigant is applied. Shank application of fumigants such as chloropicrin or chloropicrin plus 1,3 dichloropropene (Pic-Clor 60) applied at high rates under retentive film can control fungal pathogens such as *Macrophomina*.

Drip application of pre-plant fumigants may not effectively control soilborne pathogens in the entire bed; field research has demonstrated pathogen survival at the bed shoulders and in soil profiles deeper than 12 inches. Use of this application method should be considered carefully. Growers may improve fumigant distribution by using more than two drip lines per bed and by applying larger volumes of water to deliver the fumigants. Bed fumigation will not control pathogens in the untreated furrows.

Crop rotation with broccoli has been shown to help reduce *Verticillium* levels in the soil; the practice of crop rotation may also help reduce *Macrophomina* levels; it has not yet been thoroughly researched but is under investigation.

#### Cultural Control

##### *Strawberry Cultivars*

The following cultivars are listed in order of decreasing susceptibility to *Macrophomina* crown rot: Monterey, San Andreas, Albion, Fronteras, Portola, and Petaluma. Additional research is being conducted to develop new resistant cultivars.

##### *Manage Stress*

Manage the strawberry crop so as to reduce stress on the plants. Managing plant stress is more important for managing *Macrophomina* crown rot than for any of the other soilborne diseases. Irrigate the crop as appropriate for the stage of development, current evapotranspiration requirement, and soil moisture levels. Plants at the edge of the bed may be more prone to collapse due to drying or other factors associated with this location in the bed. Control pests, especially mites, which can exert significant stress on strawberry plants.

##### *Crop Rotation*

Rotating strawberries with broccoli can significantly reduce levels of the *Verticillium* pathogen in the soil. While not yet tested with *Macrophomina*, broccoli rotations may also be useful.

### Organically Acceptable Methods

Select fields that do not have a history of *Macrophomina* crown rot. Plant tolerant cultivars. Rotate with nonsusceptible crops or with crops, such as broccoli, which have the capacity to suppress the pathogen. Avoid stressing plants.

### Monitoring and Treatment Decisions

If drip fumigation is planned, good results have been obtained with a sequential application of chloropicrin or 1,3-dichloropropene plus chloropicrin followed 7 days later with metam sodium or metam potassium.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide’s properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

#### PREPLANT FUMIGATION

*Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.*

- |    |  |   |                        |        |
|----|--|---|------------------------|--------|
| A. | METHYL BROMIDE*§ / CHLOROPICRIN*§  | Label rates                             | See label              | 0      |
|    | COMMENTS: Methyl bromide use is allowed <b>only in strawberry nurseries</b> through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.   |   |                        |        |
| B. | SEQUENTIAL APPLICATION   |   |                        |        |
|    | <i>First, apply one of the following</i>   |   |                        |        |
|    | • 1,3-DICHLOROPROPENE*§<br>(Telone II)   | 100–265 lb (shank)                      | See label              | 0      |
|    | COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. One gallon of product weighs 10.1 lb.   |   |                        |        |
|    | ... or ...   |   |                        |        |
|    | • 1,3-DICHLOROPROPENE*§ / CHLOROPICRIN*§<br>(Telone C35)<br>(InLine)   | Label rates<br>Label rates (drip)       | See label<br>See label | 0<br>0 |
|    | COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. According to state permit conditions, the maximum application rate of 1,3-dichloropropene is 332 pounds active ingredient per acre. One gallon of product weighs 11.2 lb.   |   |                        |        |
|    | ... or ...   |   |                        |        |
|    | • CHLOROPICRIN*§<br>(Tri-Clor)<br>(Tri-Clor EC)  | 150–350 lb (shank)<br>200–300 lb (drip) | See label<br>See label | 0<br>0 |
|    | COMMENTS: Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.   |   |                        |        |
|    | ... or ...   |   |                        |        |
|    | • CHLOROPICRIN*§ / 1,3 DICHLOROPROPENE*§<br>(Pic-Clor 60)<br>(Pic-Clor 60EC)   | 300–332 lb (shank)<br>200–300 lb        | See label<br>See label | 0<br>0 |
|    | COMMENTS: Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. According to state permit conditions, the maximum application rate of 1,3-dichloropropene is 332 pounds active ingredient per acre. Pic-Clor 60: One gallon of weighs 12.1 lb; Pic-Clor 60 EC: One gallon of weighs 11.8 lb. |   |                        |        |

*Then, 5-7 days after fumigation apply one of the following*

- METAM SODIUM\*§

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Vapam HL, Sectagon 42) COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium. ... or ...	37.5–75 gal	See label	0
• METAM POTASSIUM*§ (K-Pam HL, Sectagon-K54) COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of K-Pam HL contains 5.8 lb of metam potassium; one gallon of Sectagon-K54 contains 5.63 lb of metam potassium.	30–62 gal	See label	0
C. DAZOMET* (Basamid) COMMENTS: Powder incorporated into the soil, followed by irrigation or tarping. It decomposes to a gaseous fumigant (methyl isothiocyanate).	200 lb	See label	0

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

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

## MUCOR FRUIT ROT (7/18)

**Pathogen:** *Mucor* spp.

### SYMPTOMS AND SIGNS

Like the fungus that causes Rhizopus fruit rot, *Mucor* spp. invade the fruit through the slightest wound. The fungus secretes an enzyme that rapidly liquifies the entire fruit. Under conditions of high humidity, the berry becomes covered with a coat of tough, wiry mycelium and black sporulation at the tips of long spore-bearing structures. *Mucor* and Rhizopus fruit rots closely resemble each other and may be difficult to differentiate in the field.

### COMMENTS ON THE DISEASE

Because the fungus lives on dead and decaying organic matter, field sanitation is important. The disease is particularly prevalent during periods of warm weather in late summer.

### MANAGEMENT

Remove all ripe fruit and plant debris from the field. Remove and destroy all ripe and near-ripe fruit from fields after rains. Use plastic mulch to keep fruit from contacting soil. Practice good sanitation during harvest, packing, transport, and storage, and avoid damaging fruit at all times. Unlike *Rhizopus*, some *Mucor* species such as *M. mucedo* and *M. piriformis* are not inhibited by cold temperatures.

#### Cultural Control

Field sanitation is extremely important. Handle fruit with care at all times. Remove all ripe fruit from the field at harvest and avoid packing overripe fruit. Be sure when fruit is being picked that the entire fruit is removed from the stem, not leaving behind the fleshy receptacle of the fruit as it can serve as a site for invasion by fungus.

#### Organically Acceptable Methods

Use sanitation, cultivar selection, and rapid postharvest cooling.

#### Treatment Decisions

Fungicide treatment is generally not recommended.

# PHYTOPHTHORA CROWN AND ROOT ROT (7/18)

**Pathogens:** *Phytophthora cactorum*, *P. citricola*, *P. parasitica*, and *P. megasperma*

## SYMPTOMS AND SIGNS

Initially, symptoms typically include plant stunting and small leaves. As the season progresses, plant collapse may occur rapidly or slowly. When infected plants are cut open, a brown discoloration can be seen in the crown vascular tissue or throughout the crown tissue. Infection of the roots causes a brown to black root rot.

## COMMENTS ON THE DISEASES

Of the *Phytophthora* species involved, *P. cactorum* is the most common; the others are much less prevalent on strawberry. *Phytophthora* is soilborne. When the soil becomes saturated with water, the pathogen can produce and release zoospores, which swim through water-filled soil pores to infect plant tissue. *Phytophthora* species also produce resilient spores (chlamydospores, oospores) that enable them to survive in soil for long periods without a host or under adverse conditions. Infections can occur during cool to moderate temperatures, which are typical throughout coastal fruit-production cycles.

## MANAGEMENT

Soil fumigation and good cultural practices provide adequate control of *Phytophthora* in production fields. Good cultural practices include the use of certified transplants, avoiding poorly drained soils, and preparing fields to provide good soil drainage during wet weather. *Phytophthora* can be moved in water that has drained from infested fields, so avoid using runoff water for irrigation or for wetting down field roads for dust control. Plant less-susceptible cultivars, such as Fronteras, Merced, Albion, San Andreas, and Portola. Even with tolerant cultivars, however, it is important to follow good cultural practices.

### Cultural Control

- Use raised beds and carefully manage drip irrigation; plant in noninfested soils that have good drainage.
- Use clean plant stock and consult your farm advisor about cultivar susceptibility.
- For non-coastal, warmer regions consider soil solarization.

### Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30-45 days of hot weather that promotes soil temperatures of at least 122°F). The effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

### Organically Acceptable Methods

Use good cultural practices such as pathogen-free planting stock, resistant or tolerant varieties and careful water and soil management (improving soil drainage; raised beds).

### Treatment Decisions

If drip fumigation is planned, good results have been obtained with a sequential application of chloropicrin or 1,3-dichloropropene plus chloropicrin followed 7 days later with metam sodium or metam potassium. Preplant dips and foliar sprays with fosetyl-aluminum or postplant ground or drip applications of mefenoxam are advisable when *Phytophthora*-susceptible cultivars are used or when field history or environmental conditions suggest significant disease risk.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*



Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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**PREPLANT FUMIGATION**

*Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.*

- A. METHYL BROMIDE\*<sup>S</sup> / CHLOROPICRIN\*<sup>S</sup>  
 (Tri-Con 50/50) 300–400 lb See label 0  
 COMMENTS: Methyl bromide use is allowed **only in strawberry nurseries** through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.
- B. SEQUENTIAL APPLICATION  
*First, apply one of the following*
- 1,3-DICHLOROPROPENE\*<sup>S</sup> / CHLOROPICRIN\*<sup>S</sup>  
 (Telone C35) Label rates See label 0  
 (InLine) Label rates (drip) See label 0  
 COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb.  
*... or ...*
  - CHLOROPICRIN\*<sup>S</sup>  
 (Tri-Clor) 150–350 lb (shank) See label 0  
 (Tri-Clor EC) 200–300 lb (drip) See label 0  
 COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.  
*Then, 5-7 days after fumigation apply one of the following*
  - METAM SODIUM\*<sup>S</sup>  
 (Vapam HL, Sectagon 42) 37.5–75 gal See label 0  
 COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  
*... or ...*
  - METAM POTASSIUM\*<sup>S</sup>  
 (K-Pam HL) 30–62 gal See label 0  
 COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.
- C. 1,3-DICHLOROPROPENE\*<sup>S</sup> / CHLOROPICRIN\*<sup>S</sup>  
 (Telone C35) Label rates See label 0  
 COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. One gallon of product weighs 11.2 lb.
- D. CHLOROPICRIN\*<sup>S</sup> 300 lb See label 0

**DURING AND AFTER PLANTING**

- A. PHOSPHOROUS ACID  
 (Fosphite) 1–3 qt 4 0  
 MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33)  
 COMMENTS: Do not apply with copper-based fungicides or fertilizers; allow 20 days after or 10 days before a copper treatment.
- B. FOSETYL-AL  
 (Aliette WDG) 2.5 lb / 100 gal for plant dips 12 0  
*... or ...*

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
<p>MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33)</p> <p>COMMENTS: May be applied as a preplant dip and as a foliar spray, beginning 14 to 21 days after planting and continuing at 30- to 60-day intervals when conditions favor disease development. See manufacturer precautions on product label regarding copper, buffering, adjuvants, and surfactants.</p>	2.5–5 lb/acre for postplant foliar sprays	12	0
<p>C. MEFENOXAM (Ridomil Gold SL)</p> <p>MODE-OF-ACTION GROUP NAME (NUMBER): Phenylamide (4)</p> <p>COMMENTS: May be applied with ground application equipment or through drip irrigation systems. In fruit production fields, apply just after planting; up to two additional applications may be made according to label guidelines.</p>	1 pt	48	0

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

# POWDERY MILDEW (7/18)

**Pathogen:** *Podosphaera aphanis*

## SYMPTOMS AND SIGNS

Leaves infected with powdery mildew initially have small, white powdery colonies on the undersides of leaves. These colonies enlarge to cover the entire lower leaf surface, causing the edges of the leaves to roll up. Purple reddish blotches appear on the upper and lower surface of leaves. Infected flowers produce deformed fruit or no fruit at all. Severely infected flowers may be completely covered by mycelium and killed. Infected immature fruits become hardened and desiccated. Infected mature fruits become seedy in appearance and support spore-producing colonies that look powdery and white.

## COMMENTS ON THE DISEASE

The disease overwinters as mycelium on leaves in California, so it is most likely introduced into the field through planting material or spores from neighboring fields. Spores are wind disseminated and short-lived. The pathogen also survives as mycelium and chasmothecia (closed spore-bearing structures) on plants coming from nurseries. Ideal conditions for infection are dry leaf surfaces, high relative humidity, and cool to warm air temperatures. Accordingly, the disease is mostly limited to the coastal growing regions and northern nurseries and causes very little damage in inland growing regions. Powdery mildew is particularly severe in greenhouse and plastic tunnel production systems.

## MANAGEMENT

During routine field surveys, watch for the leaf distortion and discoloration that are the first signs of powdery mildew, especially in fall and spring. To control powdery mildew, apply fungicides when disease is first detected. This is especially important for protectants such as sulfur. Controlling powdery mildew in the fall reduces the amount of disease that develops the following spring, and controlling foliar disease helps prevent fruit infections. The standard nursery practice of removing leaves from transplants during harvest and packing helps minimize introduction of the disease, although inoculum may still be present on crowns. Cultural practices are important in helping to prevent disease buildup.

### Cultural Control

Avoid overhead irrigation and excess use of nitrogen. Use less-susceptible cultivars, such as Albion, San Andreas, and Fronteras, where practical.

### Organically Acceptable Methods

Apply mined sulfur or insecticidal soap on organically certified strawberries. Use less-susceptible cultivars where practical. Select field sites where environmental conditions are not conducive to disease development.

### Treatment Decisions

Apply fungicides about 1 month after planting and again 3 to 4 weeks later. Make additional fungicide applications when plants begin to bloom.

Common name Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
<i>Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.</i>			
A. PYRACLOSTROBIN/FLUXAPYROXAD (Merivon) MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11) and succinate dehydrogenase inhibitor (7)	4–7 fl oz	12	0
B. QUINOXYFEN (Quintec) MODE-OF-ACTION GROUP NAME (NUMBER): Quinoline (13)	4–6 fl oz	12	1
C. PENTHIOPYRAD			

Common name Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Fontelis) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7)	16–24 fl oz	12	0
D. MYCLOBUTANIL (Rally 40W) MODE-OF-ACTION GROUP NAME (NUMBER): Demethylation inhibitor (3) COMMENTS: There may be some resistance to this fungicide. Apply in a minimum of 100 gal water/acre. Do not apply more than 30 oz/acre per year.	2.5–5.0 oz	24	0
E. TRIFLUMIZOLE (Procure 480SC) MODE-OF-ACTION GROUP NAME (NUMBER): Demethylation inhibitor (3)	4–8 oz	12	1
F. FLUOPYRAM/TRIFLOXYSTROBIN (Luna Sensation) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7) and quinone outside inhibitor (11)	4–7.6 fl oz	12	0
G. FLUOPYRAM (Luna Privilege) MODE-OF-ACTION GROUP NAME (NUMBER): Succinate dehydrogenase inhibitor (7)	6.84 fl oz	12	See label
H. TETRACONAZOLE (Mettle 125ME) MODE-OF-ACTION GROUP NAME (NUMBER): Demethylation inhibitor (3)	3–5 fl oz	12	0
I. CYFLUFENAMID (Torino) MODE-OF-ACTION GROUP NAME (NUMBER): Phenyl-acetamide (U6)	3.4 oz	4	0
J. PYRACLOSTROBIN/BOSCALID (Pristine) MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11) and Carboxamide (7) COMMENTS: Under warm, sunny conditions, fruit bronzing may occur. To limit the potential for development of resistance do not make more than five applications of strobilurin or anilide fungicides per season. Do not make more than three sequential applications of this fungicide before rotating to a fungicide with a different mode of action.	18.5–23 fl oz	12	0
K. MICRONIZED SULFUR# MODE-OF-ACTION GROUP NAME (NUMBER): Multi-site contact (M2) COMMENTS: Sulfur application during high temperatures may burn foliage. Do not apply within 3 weeks of an oil application.	5–10 lb	24	0
L. AZOXYSTROBIN (Quadris Top) MODE-OF-ACTION GROUP NAME (NUMBER): Quinone outside inhibitor (11) COMMENTS: Do not apply more than two consecutive foliar applications before switching to alternative chemistry. Do not apply more than 1 lb a.i./acre per season.	12–14 fl oz	12	0
M. INSECTICIDAL SOAP# (M-Pede) MODE-OF-ACTION GROUP NAME (NUMBER): A contact fungicide with smothering and barrier effects. COMMENTS: The potential for phytotoxicity has not been fully evaluated. Growers are encouraged to test product or product mixes for phytotoxicity before field applications to determine safety margins. Do not use on new transplants, unrooted cuttings, or water-stressed plants. Avoid applying when leaf temperature exceeds 90°F. Thorough coverage is important. Avoid spraying when blossoms are present.	1.25–2.5 fl oz/gal	12	0

\*\* Apply all pesticides in 200 gal water/acre to ensure adequate coverage.

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

# Acceptable for use on organically grown produce.

Common name Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

## RED STELE (7/18)

**Pathogen:** *Phytophthora fragariae* var. *fragariae*

### SYMPTOMS AND SIGNS

Symptoms of red stele include severe stunting, occasionally followed by death of plants. Symptoms first appear on plants located in low, poorly drained parts of the field. Affected plants become stunted as older leaves die and are replaced by smaller, younger leaves with short petioles. Young lateral roots are often completely rotted. New crown roots die back from their tips, producing a symptom called "rat tail." Splitting affected roots reveals the red stele symptom (red coloration in the core of the root above the rotted end) from which the disease gets its name. Red stele can also cause a dark brown discoloration of the crown; this symptom is identical to that caused by other *Phytophthora* species that infect strawberry.

### COMMENTS ON THE DISEASE

Most infections are limited to winter and early spring in California. Optimum conditions for disease development occur when the soil is water-saturated during cool weather. Under these conditions the pathogen produces zoospores (motile spores) that swim to the roots and infect them. Well-drained soil can minimize disease incidence and severity.

### MANAGEMENT

To minimize disease incidence and severity:

- Locate strawberry fields on well-drained soil.
- Plant annually with certified transplants.
- Fumigate the soil before planting.
- Use raised beds to provide optimum drainage.
- Avoid excessive or insufficient amounts of irrigation water.
- Consider using systemic fungicides.

There are no commercially available California strawberry cultivars with resistance to the pathogen that causes red stele.

#### Cultural Control

- Use raised beds.
- Carefully manage drip irrigation.
- Plant in noninfested soils that have good drainage.
- Use clean plant stock.
- Consider soil solarization.

#### Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30-45 days of hot weather that promotes soil temperatures of at least 122°F). The effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

#### Organically Acceptable Methods

Control red stele with cultural controls in organically certified strawberries.

#### Treatment Decisions

If drip fumigation is planned, good results have been obtained with a sequential application of chloropicrin or 1,3-dichloropropene plus chloropicrin followed 7 days later with metam sodium or metam potassium. Preplant dips and foliar sprays with fosetyl-aluminum or postplant ground or drip applications of mefenoxam are advisable when field history or environmental conditions suggest significant disease risk.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

### PREPLANT FUMIGATION

Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.

- |    |  |                    |           |   |
|----|--|--------------------|-----------|---|
| A. | METHYL BROMIDE*§ / CHLOROPICRIN*§<br>(Tri-Con 50/50)   | 300–400 lb         | See label | 0 |
|    | COMMENTS: Methyl bromide use is allowed <b>only in strawberry nurseries</b> through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.   |                    |           |   |
| B. | SEQUENTIAL APPLICATION<br><i>First, apply one of the following</i>   |                    |           |   |
|    | • 1,3-DICHLOROPROPENE*§ / CHLOROPICRIN*§<br>(Telone C35)   | Label rates        | See label | 0 |
|    | (InLine)   | Label rates (drip) | See label | 0 |
|    | COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb.   |                    |           |   |
|    | ... or ...   |                    |           |   |
|    | • CHLOROPICRIN*§<br>(Tri-Clor)   | 150–350 lb (shank) | See label | 0 |
|    | (Tri-Clor EC)  | 200–300 lb (drip)  | See label | 0 |
|    | COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb. |                    |           |   |
|    | <i>Then, 5–7 days after fumigation apply one of the following</i>  |                    |           |   |
|    | • METAM SODIUM*§<br>(Vapam HL, Sectagon 42)  | 37.5–75 gal        | See label | 0 |
|    | COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  |                    |           |   |
|    | ... or ...   |                    |           |   |
|    | • METAM POTASSIUM*§<br>(K-Pam HL)  | 30–62 gal          | See label | 0 |
|    | COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.  |                    |           |   |

### DURING AND AFTER PLANTING

- |    |   |   |    |   |
|----|---|---|----|---|
| A. | PHOSPHOROUS ACID<br>(Fosphite)  | 1–3 qt                                    | 4  | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33)  |   |    |   |
|    | COMMENTS: Do not apply with copper-based fungicides or fertilizers; allow 20 days after or 10 days before a copper treatment. |   |    |   |
| B. | FOSETYL-AL<br>(Aliette WDG)   | 2.5 lb/100 gal for plant dips             | 12 | 0 |
|    | ... or ...  |   |    |   |
|    |   | 2.5–5 lb/acre for postplant foliar sprays | 12 | 0 |
|    | MODE-OF-ACTION GROUP NAME (NUMBER): Phosphonate (33)  |   |    |   |

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
<p>COMMENTS: May be applied as a preplant dip and as a foliar spray, beginning 14 to 21 days after planting and continuing at 30- to 60-day intervals as long as conditions favor disease development. See manufacturer precautions on product label regarding copper, buffering, adjuvants, and surfactants.</p>			
<p>C. MEFENOXAM (Ridomil Gold SL)</p>	1 pt	48	0
<p>MODE-OF-ACTION GROUP NAME (NUMBER): Phenylamide (4)</p> <p>COMMENTS: May be applied with ground application equipment or through drip irrigation systems. In fruit production fields, apply just after planting; up to two additional applications may be made according to label guidelines.</p>			

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.



## RHIZOPUS FRUIT ROT (LEAK) (7/18)

**Pathogen:** *Rhizopus* spp.

### SYMPTOMS AND SIGNS

Initial infections of *Rhizopus* fruit rot appear as discolored, water-soaked spots on fruit. These lesions enlarge rapidly, aided by enzymatic breakdown that leaves the berry limp, brown, and whose contents leak out onto the bed. Under conditions of high relative humidity, the berry rapidly becomes covered with a coat of white mycelium and sporangiophores. The sporangiophores develop black, spherical sporangia, each containing thousands of spores. When disrupted, these sporulating berries release a cloud containing millions of spores.

*Rhizopus* and *Mucor* fruit rots closely resemble each other but can be differentiated in the field by examining the fungal growth with a hand lens. Look for the tiny, dark brown to black, spherical structures on the ends of the white fungal strands. These black spheres are the spore-bearing structures, or sporangia. For *Rhizopus* the sporangia appear dry, while the *Mucor* sporangia are wet or sticky looking due to a viscous liquid film.

### COMMENTS ON THE DISEASE

The fungus is an excellent saprophyte that lives on and helps break down decaying organic matter. It invades strawberries through wounds and secretes enzymes that degrade and kill the tissue ahead of the actual fungal growth. The fungus is especially active during the warmer months in late summer and survives cold periods as mycelium or spores on organic debris. Spores are airborne. The pathogen has a wide host range and is prevalent worldwide.

### MANAGEMENT

*Rhizopus* stops growing at temperatures below 46° to 50°F (8° to 10°C), so rapid postharvest cooling of fruit is essential for disease control. Field sanitation also is extremely important: do not leave discarded plant refuse or berries in the furrows and be sure to remove all ripe fruit from the field.

#### Cultural Control

Field sanitation is extremely important. Handle fruit with care at all times. Remove all ripe fruit from the field at harvest. Be sure when fruit is being picked that the entire fruit is removed from the stem, not leaving behind the fleshy receptacle of the fruit as it can serve as a site for invasion by fungus.

#### Organically Acceptable Methods

Use sanitation, cultivar selection, and rapid postharvest cooling.

#### Treatment Decisions

Fungicide applications are not currently recommended

## STRAWBERRY LEAF BLOTCH (7/18)

**Pathogen:** *Zythia fragariae*

### SYMPTOMS AND SIGNS

Strawberry leaf blotch is most often found early in the season following heavy rainfall. Symptoms consist of tan to gray lesions that quickly expand from the leaf margins on the first few leaves of the new plant. The lesions, which most often begin at leaflet margins, can grow to cover the entire leaflet surface. The presence of very small black to brown fruiting bodies inside the lesions is a diagnostic sign of this disease. This pathogen can also cause black to brown lesions on the petiole, as well as a brown blight of the calyx and decay on the calyx end of the strawberry fruit.

### COMMENTS ON THE DISEASE

*Zythia fragariae* is dependent on splashing water for spread of inoculum, and the disease is therefore much more common in winter and early spring. This pathogen survives on strawberry residue in the soil and most likely will not persist in the absence of this residue.

### MANAGEMENT

Leaf blotch has been a minor problem in California, and strawberry plants grow out of this disease when the winter rains stop. Fungicide applications are not recommended.

## VERTICILLIUM WILT (7/18)

**Pathogen:** *Verticillium dahliae*

Infected plants may initially be stunted. Outer leaves exhibit marginal and interveinal browning, followed by eventual collapse. Inner leaves remain green. This last symptom sometimes helps to distinguish this disease from *Phytophthora* crown rot.

### COMMENTS ON THE DISEASE

The fungus is not host-specific and infects many weed species and crops worldwide. It is especially destructive in semi-arid areas where soils are irrigated. Inoculum densities may be high following planting of susceptible crops (e.g., lettuce). Disease severity is greater when high levels of nitrogen are used.

### MANAGEMENT

Preplant fumigation is an important component of managing *Verticillium* wilt in strawberry fields. If fumigation is not desirable, select fields isolated from established growing areas, avoiding any fields with detectable levels of the pathogen or with a history of susceptible crops. Crop rotation with broccoli and incorporating residue during warm parts of the year has been shown as an effective way to reduce *Verticillium* in the soil. Solarization of formed beds may be used to reduce pathogen levels in areas that get adequate amounts of sunshine and warm weather during summer months, although the usefulness of this technique for reducing *Verticillium* wilt in strawberries is unknown.

#### Cultural Control

If infested fields cannot be avoided and fumigation is not feasible, either solarize the soil or implement a crop rotation program. Cover crops of cereal rye or ryegrass can help to reduce soil levels of *Verticillium*. Use relatively tolerant strawberry cultivars when practical; Camino Real, Petaluma, Albion, and San Andreas are among the least susceptible UC cultivars.

#### Soil Solarization

In warmer areas of the state, solarization has been shown to be effective for the control of soilborne pathogens and weeds. Solarization is carried out after the beds are formed and can be effective if weather conditions are ideal (30-45 days of hot weather that promotes soil temperatures of at least 122°F). The effectiveness of solarization can be increased by solarizing after incorporating the residue of a cruciferous crop, in particular broccoli or mustards, into the soil or following an application of metam sodium (40 gal/acre). For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

#### Crop Rotation

Rotating strawberries with broccoli can significantly reduce levels of the *Verticillium* pathogen in the soil and has been shown to be an economically viable option under moderate levels of *Verticillium* wilt disease pressure.

#### Organically Acceptable Methods

Select fields isolated from established growing areas. If fields have detectable levels of the pathogen or a history of susceptible crops, plan to solarize the soil, preferably after incorporating the crop residue from broccoli or mustards. Use drip irrigation and resistant cultivars (e.g., Camino Real, Petaluma, San Andreas or Albion). Practice crop rotation with a nonsusceptible crop, such as broccoli, and avoid high nitrogen fertilizers.

#### Treatment Decisions

Drip fumigation of pre-plant fumigants may not effectively control soilborne pathogens in the entire bed; field research has demonstrated pathogen survival at the bed shoulders and in soil profiles deeper than 12 inches. Use of this application method should be considered carefully. Growers may improve fumigant distribution by using more than two drip lines per bed and by applying larger volumes of water to deliver the fumigants. Bed fumigation will not control these pathogens in the untreated furrows.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
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Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide’s properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

**PREPLANT FUMIGATION**

Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.

- |    |  |                    |           |   |
|----|--|--------------------|-----------|---|
| A. | METHYL BROMIDE*§ / CHLOROPICRIN*§<br>(Tri-Con 50/50)   | 300–400 lb         | See label | 0 |
|    | COMMENTS: Methyl bromide use is allowed <b>only in strawberry nurseries</b> through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.   |                    |           |   |
| B. | SEQUENTIAL APPLICATION<br><i>First, apply one of the following</i>   |                    |           |   |
|    | • 1,3-DICHLOROPROPENE*§ / CHLOROPICRIN*§<br>(Telone C35)   | Label rates        | See label | 0 |
|    | (InLine)   | Label rates (drip) | See label | 0 |
|    | COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. InLine requires a plastic tarp. Use higher rates or impermeable films to improve weed and nematode control. One gallon of product weighs 11.2 lb.   |                    |           |   |
|    | ... or ...   |                    |           |   |
|    | • CHLOROPICRIN*§<br>(Tri-Clor)   | 150–350 lb (shank) | See label | 0 |
|    | (Tri-Clor EC)  | 200–300 lb (drip)  | See label | 0 |
|    | COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb. |                    |           |   |
|    | <i>Then, 5-7 days after fumigation apply one of the following</i>  |                    |           |   |
|    | • METAM SODIUM*§<br>(Vapam HL, Sectagon 42)  | 37.5–75 gal        | See label | 0 |
|    | COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  |                    |           |   |
|    | ... or ...   |                    |           |   |
|    | • METAM POTASSIUM*§<br>(K-Pam HL)  | 30–62 gal          | See label | 0 |
|    | COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.  |                    |           |   |

\*\* Rates are per treated acre; for bed applications, the rate per acre may be lower.

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

<sup>1</sup> Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action (for more information, see <http://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 a fungicide with a different mode-of-action group number.

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

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

## VIRUS DECLINE OF STRAWBERRY (7/18)

**Pathogens:** Virus complex consisting of whitefly-transmitted viruses, *Strawberry pallidosis associated virus* (SPaV) or *Beet pseudo yellows virus* (BPYV), in combination with any one of several non-whitefly transmitted viruses.

### SYMPTOMS AND SIGNS

Symptoms of this virus disease resemble those of nutritional deficiencies and other abiotic disorders and can be difficult to diagnose and confirm in the field. Leaves of strawberry plants with virus decline turn purple to red in color. New growth may appear in the center of plants with young leaves that remain green. Plants affected early in their development are often stunted. Diseased plants have greatly reduced fruit production, and roots are brittle with reduced numbers of small absorptive rootlets.

Outbreaks of virus decline are usually associated with the presence of the greenhouse whitefly vector *Trialeurodes vaporariorum*, as well as aphids that can transmit most of the non-whitefly-transmitted viruses associated with this disease. Increased numbers of the greenhouse whitefly in the field have been correlated with increased disease incidence in coastal strawberry fields in recent years. The absence of vectors when symptoms are observed, however, does not rule out the possibility of strawberry decline. Young strawberry plants may be infected by either a whitefly- or aphid-transmitted virus but remain symptomless. Introduction of an additional virus at a later date by a different vector would lead to disease development. Strawberry plants are usually symptomless if infected with only SPaV or BPYV.

### COMMENTS ON THE DISEASE

The presence of BPYV or SPaV alone or together will not cause this disease. For virus decline to occur, strawberry plants must be infected with either SPaV or BPYV as well as any of several viruses transmitted by aphids. Non-whitefly-transmitted viruses that have been found associated with strawberry decline include *Strawberry crinkle virus*, *Strawberry vein banding virus*, *Strawberry mottle virus*, and *Strawberry mild yellow edge virus*. Other viruses such as *Strawberry latent ringspot* and *Fragaria chiloensis latent viruses* were recently identified in California strawberry plantings. Their potential roles in virus decline are being examined.

SPaV and BPYV are members of the genus *Crinivirus*. SPaV has a narrow host range and is primarily limited to strawberry and related species but can also infect a few common weeds. BPYV has an extensive host range and infects many plants in addition to strawberry, including cucurbits and numerous weeds common in coastal production areas.

Confirmation of virus infection requires testing plant material with molecular or serological techniques.

### MANAGEMENT

- When available, use transplants that are not infected with SPaV or BPYV.
- Control the greenhouse whitefly and aphid vectors.
- Remove weeds and alternate crop hosts of BPYV and SPaV, which may be virus reservoirs, prior to planting strawberry to prevent movement of virus-carrying whiteflies into the strawberry crop.

## Nematodes

(Section reviewed 7/18)

**Scientific Names:** Foliar nematode: *Aphelenchoides fragariae*  
Northern root-knot nematode: *Meloidogyne hapla*

### DESCRIPTION OF THE PESTS

Plant parasitic nematodes are microscopic, unsegmented roundworms. The two species most commonly associated with damage in California strawberries are the foliar nematode, *Aphelenchoides fragariae*, and the northern root-knot nematode, *Meloidogyne hapla*. The northern root-knot nematode is found in the soil or as a sedentary endoparasite (an immobile life stage inside the plant tissue) in roots. The foliar nematode is a parasite of aboveground plant parts (stems and leaves) and may be endo- or ectoparasitic. Symptoms caused by *A. fragariae* are sometimes called spring crimp, spring dwarf, or strawberry crimp. However, these names are misleading and should not be used in California because nematodes and associated symptoms may be present during seasons other than spring and other symptoms may be more important than crimp in recognizing the presence of the nematode.

Although *A. fragariae* and *M. hapla* have been most frequently associated with damage in California, strawberries are also hosts for the following nematodes:

- root lesion (*Pratylenchus penetrans*),
- stem (*Ditylenchus dipsaci*),
- dagger (*Xiphinema americanum*),
- needle (*Longidorus elongatus*),
- foliar (*Aphelenchoides ritzemabosi* and *A. besseyi*), and
- root knot (*Meloidogyne incognita* and *M. javanica*).

All of these nematodes are potential pathogens to strawberries in California and their identification in strawberry plantings or in land to be planted to strawberries should be cause for concern.

### DAMAGE

The presence of either foliar or northern root-knot nematodes may cause plant stress and reduce yields. Past (and current) fumigation practices have resulted in these nematodes not being widely present in strawberry production fields. However, with the increasing use of organic methods, which do not include the use of fumigants, infestations and damage may become more common. Control of these two pests by nursery stock producers is critical because it greatly reduces the risk of spreading these nematode pests throughout California. Additionally, an infestation will prevent nursery producers from receiving government certification, thereby greatly reducing the value of the planting stock.

### SYMPTOMS AND SIGNS

Plant symptoms can be indicative of a nematode problem but are not diagnostic because similar symptoms could result from other problems as well, such as nutrient deficiency, soil texture, or soil moisture. The symptoms may either be widespread or may appear in small patches within a field.

#### Foliar nematode

Aboveground symptoms include stunted growth, reddened leaves, small curled or crinkled leaves (crimp), deformed buds and flowers, and a reduction in flowering and fruiting. Research conducted in California on the Chandler cultivar, as well as older cultivars such as Douglas, Fern, Pajaro, and Selva showed that a reduction in flowering and fruiting may more reliably distinguish a foliar nematode infestation from insect infestations, which also produce leaf symptoms similar to those described above. Similar data on more current cultivars are not available, but the same may be true. There are no reported belowground symptoms with this species.

#### Root-knot nematodes

Aboveground symptoms include wilting during hot days, stunting, chlorosis, and reduction of yields. Root galls formed near the root tips and prolific root branching at and above these galls are the primary belowground symptoms of this pest.

### FIELD EVALUATION

To make proper management decisions, it is important to determine which nematode species are present. Take plant or soil samples (or both) and send them to a diagnostic laboratory for identification.

In an existing strawberry crop:

1. Examine the field for symptoms described above.
2. Dig up the entire suspected plant, place the plant and surrounding soil into a plastic bag.
3. Take a separate sample from an area without symptoms for comparison.

In fallow fields or fields in other crops:

1. Visually divide the field into sampling blocks that represent differences in soil texture, drainage patterns, or cropping history, but are not larger than 5 acres in size.
2. Take a separate sample from each block so that each can be managed individually.
3. Sample when the soil is moist and sample at the rooting depth of the current or previous crop.
4. Collect at least 10 subsamples from different parts of the field.
5. Mix these subsamples well and place about 1 quart of soil per sample into a plastic bag. If possible, place roots from the crop in the bag with the soil.

Seal bags, place a label on outside of the bag, keep the sample cool (do not freeze), and transport as soon as possible to a diagnostic laboratory. Inform the laboratory that you want to know if the nematodes listed as pests above are present so they can use appropriate extraction techniques. Request a diagnosis to species. Keep in mind that nematode sampling and extraction techniques are typically 30 to 50% effective in finding species that might be present. Therefore, a negative finding does not rule out the possible presence of plant parasitic nematodes.

## MANAGEMENT TECHNIQUES

The use of certified planting stock (produced in fumigated fields) has been critical in avoiding the introduction and spread of parasitic nematodes into strawberry production fields. Combined with fumigation of production fields, this has resulted in nematodes generally not causing important problems in strawberry. For growers not satisfied with the degree of nematode control that has been achieved with the standard techniques, use of additional techniques (such as hot water treatment of infested planting stock) could increase the level of control obtained.

For growers wishing to minimize the use of chemical nematicides, using a combination of other techniques should provide some degree of nematode control. However, the same dollar input will probably not equal the control or yields achieved with fumigation, although the costs could perhaps be offset by higher returns for organically produced strawberries. Alternative techniques often require more advanced planning than the use of traditional chemical management techniques, may not be applicable to all growing situations, and should first be attempted on a small scale.

Nonchemical alternatives to nematicides include:

- select a planting site free of plant-parasitic nematodes
- clean equipment to minimize nematode transfer
- avoid nematode-infested irrigation water
- use hot water treatments of planting stock
- plant when environmental conditions are unfavorable for nematodes
- remove plants with symptoms indicating foliar nematode infestation
- rotate with broccoli and incorporate the crop residue into the soil
- fallow the field
- biological control

It is not possible to provide guidelines applicable statewide for using combinations of these techniques that might provide adequate nematode control. Growers wanting to utilize nonchemical management techniques should discuss possible solutions with their local farm advisors.

### Fumigation

With the phase-out of methyl bromide, the most effective soil fumigation is a sequential application of chloropicrin or 1,3-dichloropropene/chloropicrin followed 5 to 7 days later by metam sodium or metam potassium. This combination of pesticides can provide effective control of weeds as well as soilborne pathogens, soil insects and nematodes. 1,3-dichloropropene (Telone) is a true nematicide and, as such, is more effective against nematodes than chloropicrin. For more information on fumigation, see the DRIP FUMIGATION section.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide’s properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
-------------------------------------	--------------------	-----------------	----------------

PREPLANT FUMIGATION

*Note: Fumigants such as 1,3-dichloropropene and metam products are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone. Methyl bromide depletes ozone.*

A. METHYL BROMIDE\*§/CHLOROPICRIN\*§  
(Tri-Con 50/50) 300–400 lb See label NA  
COMMENTS: Methyl bromide use is allowed **only in strawberry nurseries** through the quarantine and pre-shipment (QPS) exemption. Fumigants such as methyl bromide are a source of volatile organic compounds (VOCs) but are not reactive with other air contaminants that form ozone: methyl bromide depletes ozone.

B. SEQUENTIAL APPLICATION

*First, apply one of the following*

- 1,3-DICHLOROPROPENE\*§/CHLOROPICRIN\*§  
(Telone C35) Label rates See label NA  
(InLine) Label rates See label NA  
COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. Use higher rates or impermeable films to improve weed and nematode control. InLine requires a plastic tarp. One gallon of product weighs 11.2 lb.  
... or ...
- 1.3-DICHLOROPROPENE\*§  
(Telone II) Label rates See label NA  
COMMENTS: Liquid that diffuses as a gas through soil. Effective against nematodes and insects. Rates vary with soil texture and efficacy strongly affected by soil moisture and temperature. One gallon of product weighs 10.15 lb.  
... or ...
- CHLOROPICRIN\*§  
(Tri-Clor EC) Label rates (drip) See label NA  
COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of TIF will improve both nematode and weed control. Tri-Clor: One gallon of product weighs 13.88 lb; Tri-Clor EC: One gallon of product weighs 13.46 lb.

*Then, 5 to 7 days after initial application, apply one of the following*

- METAM SODIUM\*§  
(Vapam HL, Sectagon 42) 37.5–75 gal See label NA  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.  
... or ...
- METAM POTASSIUM\*§  
(K-Pam HL) 30–62 gal See label NA  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

NA Not applicable

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



## *Weeds*

(Section reviewed 7/18)

# INTEGRATED WEED MANAGEMENT (7/18)

Strawberries are highly susceptible to weed competition, especially at the initial stage after planting when the plants are small and frequent irrigation provides ideal conditions for weed germination. During stand establishment, weeds such as, little mallow, burclover, sweetclover, and filaree are problematic because their seeds survive the soil fumigation. Likewise, grass species and broadleaf weeds with windblown seeds, such as annual sowthistle hairy fleabane, everlasting cudweed, and common groundsel may become problematic after planting. Perennial weeds such as field bindweed and yellow nutsedge are increasingly common in Southern California and Santa Barbara County strawberry production and may be a problem on the Central Coast, especially in fields where the crop is carried over into a second year of production. In areas where strawberries are carried over for 2 years, weed management during the second season consists of a combination of preemergence herbicides, mulches, and hand weeding.

In conventional strawberry fields, effective weed management requires a combination of cultural practices, preplant soil fumigation, and herbicide applications when necessary. Proper field and bed preparation is essential for a good weed control program. Fumigation with chloropicrin or a mixture of 1,3-dichloropropene/chloropicrin, followed by an application of oxyfluorfen, flumioxazin, metam sodium, or metam potassium, in conjunction with the use of opaque plastic mulches is a viable alternative to methyl bromide for most weed and pathogen control in California strawberries. However, these fumigants are not as effective as methyl bromide/chloropicrin at controlling nutsedges. The use of totally impermeable film (TIF) enhances weed control provided by 1,3-dichloropropene/chloropicrin (see DRIP FUMIGATION). For weeds that escape preplant controls, hand-weeding or selective herbicides (or both) are used. For weed control alone, the herbicides oxyfluorfen and flumioxazin are very effective on many annual weeds.

Several methods may be used as fumigation alternatives for weed management in strawberry production. In warmer, inland areas soil solarization can be effective at killing germinating weeds. However, the use of soil solarization is not effective in cool, coastal strawberry districts, where the best alternative method of weed control is the use of black, brown, or green mulch films. In some cases, organic mulches have been used instead of plastic mulch. Though the use of weed-free substrates eliminates initial weed control needs, infestation with wind-dispersed weeds can still occur. Soil treatment with steam is very effective in killing weeds if lethal temperatures are reached in soil where weed propagules (plant pieces that can give rise to new plants) are present, but it requires specialized equipment. Anaerobic soil disinfestation can reduce the numbers of many annual weeds but it has limited efficacy on perennial weeds. For more information on alternatives to fumigation, see the NON-FUMIGANT ALTERNATIVES section.

## FIELD SELECTION AND MONITORING

Survey the intended fields for the distribution and density of annual, biannual, and perennial weeds. Soil fumigation allows for the use of land that may have a weedy history, but less weedy sites are preferred. Certain weeds (e.g., hairy nightshade) host soilborne diseases (e.g., *Verticillium* wilt); by avoiding fields infested with these weeds, there could be a lower incidence of soilborne diseases. Weeds can be a source of food and habitat for mites and insect pests such as lygus bugs and greenhouse whitefly. Controlling weeds in the vegetative stage in and around strawberry fields helps to lower pest numbers and, additionally, prevent weed seed production and dispersal.

Before field preparation, scout the site for weeds and make notes of which weeds are present at the field site and in surrounding areas. Keep records on a monitoring form (*example form available online*). Control annual weeds before they produce seed. Control weeds in areas adjacent to strawberry fields (roadsides, ditches) before flowering to prevent their potential dispersal into the field. Pay particular attention to herbicide efficacy, since there are several modes of action to which weeds have developed resistance. Particularly common is resistance to glyphosate in horseweed and fleabane. During the early stages of plant establishment, check frequently for weeds (at least once every 3 weeks during the first 3 to 4 months after planting). Send weeding crews through and around fields, as needed, to remove perennials and purslane.

## WEED MANAGEMENT BEFORE PLANTING

### Crop Rotation

Rotational crops are an important part of a weed control program. Rotations can be with vegetable crops, caneberries, or highly competitive cover crops (cereals, cereal plus legume mixtures, and mustards). Where the cropping cycle permits, sudangrass may be included in the rotation cycle as a summer annual green manure crop. Intensive cultivation for a vegetable crop rotation such as lettuce or a cole crop helps in controlling many problematic weeds. In tunneled caneberries, a common rotational crop, weed germination is confined to plant rows and tunnel post rows that have sufficient moisture. A densely planted small grain crop is highly competitive with weeds and prevents deposits and establishment of wind-dispersed weeds.

Alternative herbicides are also available in rotations. In small grains for example, translocated broadleaf herbicides can help to control infestations of field bindweed, and contact herbicides can control broadleaf annuals. In peppers or celery, *S*-metolachlor (Dual Magnum) can be used to control yellow nutsedge.

### Cultivation

Before bed formation, sprinkler-irrigate to germinate weeds, thus reducing the weed seed reservoir in the soil. After weeds have germinated, remove the seedlings with cultivation or propane flaming. Because most California strawberries are planted in the fall, this practice can be accomplished mid-to-late summer in coastal climates where soil temperatures are usually cool enough for winter weeds to germinate year round. In the warm interior valleys, winter annuals may not germinate during this period.

### Opaque Mulches

Opaque mulches are usually dark-colored plastic films. These may be brown, black, or green, but they must restrict light from penetrating the film to be effective. Clear (transparent) plastic is sometimes used in summer in warmer areas to solarize the soil, but in winter it serves as a greenhouse and encourages both weed and strawberry plant growth. The use of clear plastic is a common practice on South Coast winter plantings because it promotes early yield (colored mulches delay fruit production). Growers who choose to use clear plastic in winter must use fumigants and herbicides to ensure that most weed seeds are killed. Plastic mulches with a clear strip covering bed-tops (to stimulate strawberry growth) and opaque strips on the sides of beds (to aid weed control) are also common.

When using opaque mulches, secure them to the soil before transplanting. Place strawberry plants in the soil after cutting a hole into the plastic at the desired spacing. Weed growth is greatly reduced with opaque mulches, but weeds will still grow in the holes where the strawberry is planted and need to be removed by hand. Use the smallest possible hole to minimize weed growth around the strawberry plants. Planting through slits in the mulch helps to minimize weed growth and seed deposition.

### Fumigation

After the phase-out of methyl bromide, the most effective soil fumigation is a sequential application of chloropicrin or 1,3-dichloropropene/chloropicrin followed 5 to 7 days later by metam sodium or metam potassium. This combination of pesticides can provide effective control of weeds as well as soilborne pathogens, soil insects and nematodes.

Fumigation with 1,3-dichloropropene (1,3-D) plus chloropicrin mixture (Telone C35, Inline, Pic-Clor 60), chloropicrin, and metam sodium before bed preparation kills the seeds of most weeds and the reproductive structures of some perennials. Nearly all fumigant applications are either immediately covered with a plastic tarp or are injected through the drip irrigation system under a plastic tarp. Drip injection of fumigants such as 1,3-D plus chloropicrin mixture or chloropicrin often improves weed control compared to shank fumigation. However, it is important to thoroughly wet the bed during fumigant injection to ensure weed control on the edges of the bed. Where drip fumigation is used, only the bed is treated, and the row middles (furrows) are left unfumigated. Use soil-applied herbicides such as oxyfluorfen, napropamide, flumioxazin, or pendimethalin to control weeds in the row middles before planting.

Soil fumigants control weeds by killing both germinating seedlings and nongerminated seeds. Chloropicrin, 1,3-D plus chloropicrin mixture (Inline, Telone C35), and metam sodium kill weed seedlings and seeds by respiration inhibition. However, to kill weed seeds, fumigants must be able to penetrate the seed coat and kill the seed embryo. It is more effective to kill moistened seed, because the seed tissues swell with water and allow the fumigant to penetrate more thoroughly. Moist seeds also have higher respiration rates and are more susceptible

to fumigants than dry seed with low respiration rates. Proper irrigation before fumigation is one of the keys to effective weed control with all fumigants. Soil temperature must be above 55°F for effective absorption of water by seeds. Preirrigation allows nondormant weed seeds to germinate, and germinating weed seedlings are readily killed by fumigation. Burclover, sweet clover, filaree, and little mallow are among the seeds that are difficult to kill with fumigation. These seeds have impermeable seed coats that limit moisture and chemical penetration, and they remain dormant in the soil.

For additional information on this process, see DRIP FUMIGATION.

### Herbicides

Herbicides such as flumioxazin and oxyfluorfen are also quite effective on annual weeds and may be used in addition to fumigation, particularly on beds that will be covered with clear plastic mulch, and in furrows.

Oxyfluorfen (GoalTender) is registered in California as a fallow bed treatment that can be used before planting a strawberry field. It is useful for controlling weeds such as filaree and little mallow, which are not controlled well by the fumigation. This treatment is compatible with drip-applied fumigants because it can be applied after the beds are formed but before the plastic mulch is installed. It must be applied 30 days before transplanting.

Oxyfluorfen has the potential for "lift-off" or co-distillation. Lift-off is not drift but instead is the movement of the herbicide with water vapor. Lift-off can move oxyfluorfen from the soil surface to susceptible strawberry foliage. Oxyfluorfen-treated soil can also be moved onto susceptible strawberry foliage as splash from sprinkler irrigation or rainfall. To ensure safety to the strawberry plants, only use oxyfluorfen if plastic mulch will be installed before strawberry transplanting.

Flumioxazin (Chateau) can be applied to bed tops in a manner similar to oxyfluorfen. Flumioxazin controls little mallow (cheeseweed), filaree, clover, and a wide range of other broadleaf weeds. Unlike oxyfluorfen, flumioxazin does not have a "lift-off" potential. It can also be applied to control weeds in furrows (with shielded sprayers) after transplanting but before strawberry flowers.

Pendimethalin (Prowl H<sub>2</sub>O) can be applied to bed tops in a manner similar to oxyfluorfen before transplanting. Pendimethalin can also be applied to the furrows after transplanting. Pendimethalin is useful for suppressing grass weeds like annual bluegrass.

Pelargonic acid (Scythe) is a postemergence herbicide that provides contact activity or burn down of a wide spectrum of weeds. It can be applied to control weeds in the furrows both before and after transplanting.

Caprylic and Capric acids (Suppress), registered for organic production, is an effective postemergence contact herbicide for most annual weeds, but it does not control perennial weeds or weeds that emerge after application.

## WEED MANAGEMENT AFTER PLANTING

During the early stages of plant establishment, mechanical (by hand through planting holes) removal of weeds from under the clear plastic mulch and from planting holes in all tarps may be necessary. Timely removal is essential to minimize weed competition.

### Herbicides

Several herbicides are currently registered for use in newly planted strawberries. Napropamide (Devrinol) and DCPA (Dacthal) are preemergence herbicides that may be applied at transplanting or during the early growth stage of strawberry. Flumioxazin (Chateau) can be used to control weeds in furrows, especially if soil in furrows has not been fumigated. Apply it with shielded sprayers after transplanting, but before strawberry flowers. Unlike oxyfluorfen, flumioxazin does not have a 'lift-off' potential, but take caution to avoid flumioxazin drift to strawberry plants on bed tops. Suppress can be applied to furrows after planting as long as precautions are taken to assure no contact with the strawberry canopy.

Sethoxydim (Poast) and clethodim (SelectMax), postemergence herbicides registered for use in strawberries, are systemic grass herbicides that can be applied to control emerged grass weeds or cereal cover crops grown in furrow bottoms. Sethoxydim and clethodim are effective on many annual and perennial grassy weeds, but sethoxydim does not control annual bluegrass or annual ryegrass. Pelargonic acid (Scythe) is a contact herbicide that burns back a broad range of weeds and is useful in fumigated fields to provide weed control in the furrows.

Each herbicide has certain time restrictions for preharvest interval. When using any herbicide always read the product label for specific instructions.

If the soil is preplant fumigated, weeds that have a hard seed coat (little mallow, burclover, and filaree) may require additional control measures. Flumioxazin is effective on little mallow and filaree if applied before the weeds have emerged; napropamide can also be effective. If the application is delayed until the planting is established, emerged weeds must be removed before herbicide application.

For second-year strawberries, napropamide, pendimethalin, or DCPA can be applied following renovation. Overhead irrigation or rainfall is essential to incorporate the herbicides into the soil.

Tolerance to napropamide has been evaluated on several strawberry varieties. When strawberries are grown on sandy soils, maximum label rates of napropamide have caused strawberry runner inhibition and some reduction in the growth of the strawberry plant. To protect early strawberry development, try to limit or avoid early applications of napropamide.

## SPECIAL WEED PROBLEMS (7/18)

### NUTSEDGES

Yellow nutsedge, *Cyperus esculentus*, spreads and reproduces primarily by tubers. Purple nutsedge, *Cyperus rotundus*, occurs in areas with wet soil conditions. It is similar to yellow nutsedge, and management strategies are the same. Tubers of both species are formed on rhizomes that penetrate up to 12 inches deep in the soil. New plants begin to form tubers when they reach the 5-leaf stage.

Yellow nutsedge is most difficult to control in nonfumigated fields and buffer zones; nutsedge tubers will often spread from one field to the other fields. Nutsedge grows actively in warm fall conditions and in summer-planted strawberries in Southern California but becomes increasingly dormant with onset of cool temperatures in winter.

Unlike other weed species, yellow nutsedge cannot be controlled by colored plastic mulch as the nutsedge shoots punctures the mulch and grow through it. To prevent this, dense materials such as water-resistant paper or recycled paper between two layers of standard plastic mulch or other weed barriers can be applied to bed tops to stop or greatly reduce shoot penetration through the plastic mulch throughout the season. Steam application has shown very good control of yellow nutsedge, but follow-up hand weeding may be necessary to eliminate nutsedge plants that may germinate from surviving tubers.

Nutsedge tubers can remain viable for about three years. Fumigation with chloropicrin or a mixture of 1,3-D and chloropicrin does not provide complete control of nutsedge. However, use of barrier films like VaporSafe with 1,3-D plus chloropicrin have been shown to improve weed control, including nutsedge. Solarization of formed beds destroys many of the tubers that are buried no deeper than 3 inches. The technique may be more effective in hotter inland locations compared to the cool coastal zones. Deep plowing to a depth of 10 or 12 inches with a moldboard plow that completely inverts the soil helps suppress infestations.

If nutsedge plants appear in strawberry plantings, remove them by hand before they reach the 5-leaf stage to prevent new tuber formation. Tubers are easily spread in soil on farm equipment that has worked on infested areas. Nutsedge infestations usually do not get established in properly fumigated strawberry fields.

### SOWTHISTLE, HAIRY FLEABANE, HORSEWEED, EVERLASTING CUDWEED, AND COMMON GROUNDSEL

Weeds with wind-dispersed seeds such as sowthistle, hairy fleabane, horseweed, everlasting cudweed, and common groundsel can move into the field at any time during the production cycle. Control weeds with wind-dispersed seeds in and around your field. Preplant herbicides such as flumioxazin, pendimethalin and oxyfluorfen are effective in managing these weeds. Pay particular attention to efficacy if glyphosate is used in adjacent areas, since horseweed and fleabane can be resistant to glyphosate. Due to labor for hand weeding, management is difficult in-season.

## COMMON AND SCIENTIFIC NAMES OF WEEDS (7/18)

Common Name	Scientific Name
barley, hare	<i>Hordeum murinum</i> ssp. <i>leporinum</i>
barnyardgrass	<i>Echinochloa crus-galli</i>
bermudagrass	<i>Cynodon dactylon</i>
bindweed, field	<i>Convolvulus arvensis</i>
bluegrass, annual	<i>Poa annua</i>
burclovers	<i>Medicago</i> spp.
chickweed, common	<i>Stellaria media</i>
everlasting cudweed	<i>Pseudognaphalium luteoalbum</i>
filarees	<i>Erodium</i> spp.
fleabane, hairy	<i>Conyza bonariensis</i>
goosefoot, nettleleaf	<i>Chenopodium murale</i>
groundsel, common	<i>Senecio vulgaris</i>
horseweed	<i>Conyza canadensis</i>
lambsquarters, common	<i>Chenopodium album</i>
mallow, little (cheeseweed)	<i>Malva parviflora</i>
nettle, burning	<i>Urtica urens</i>
nutsedge, yellow	<i>Cyperus esculentus</i>
pigweeds	<i>Amaranthus</i> spp.
pineapple-weed	<i>Matricaria discoidea</i>
puncturevine	<i>Tribulus terrestris</i>
purslane, common	<i>Portulaca oleracea</i>
ryegrass, Italian	<i>Lolium perenne</i> ssp. <i>multiflorum</i>
sowthistles	<i>Sonchus</i> spp.
sweetclovers	<i>Melilotus</i> spp.

# SUSCEPTIBILITY OF WEEDS TO HERBICIDE CONTROL (7/18)

	FUMIGANTS					PREEMERGENCE					POSTEMERGENCE					CULTURAL CONTROL
	13/C	CHL	MEB <sup>2</sup>	MEP	MET*	DCP	FLM	NAP	OXY <sup>3</sup>	PEN	CAR	CLE	PAR*	PEL	SET	Solarization
<b>Mode of Action<sup>1</sup></b>	NA	NA	NA	NA	NA	3	14	15	14	3	14	1	22	27	1	NA
<b>ANNUAL WEEDS</b>																
barley, hare	C	C	C	C	C	C	C	C	P	C	N	C	P	—	C	C
barnyardgrass	C	C	C	C	C	C	—	C	P	C	N	C	P	C	C	C
bluegrass, annual	C	C	C	C	C	C	—	C	P	C	N	C	P	C	N	C
burclovers	N	N	N	N	N	N	C	P	N	—	—	N	P	—	N	C
chickweed, common	C	C	C	C	C	C	C	C	N	C	P	N	C	C	N	C
filarees	N	N	N	P	P	P	C	C	C	N	—	N	P	P	N	C
fleabane, hairy	—	—	C	—	C	N	C	N	P	N	N	N	P	P	N	—
goosefoot, nettleleaf	C	C	C	C	C	C	C	P	C	C	—	N	C	—	N	—
groundsel, common	C	C	C	C	C	C	C	C	C	N	—	N	C	C	N	C
horseweed	—	—	—	—	C	N	C	N	P	N	N	N	P	—	N	—
lambsquarters, common	C	C	C	C	C	C	C	C	C	C	—	N	C	P	N	C
mallow, little (cheeseweed)	P	P	N	P	P	P	C	P	C	P	C	N	N	C	N	C
nettle, burning	C	C	C	C	C	C	C	P	C	N	C	N	P	—	N	C
pigweeds	C	C	C	C	C	C	C	C	C	C	C	N	C	P	N	C
pineapple-weed	C	C	C	C	C	P	—	P	P	N	—	N	P	—	N	C
puncturevine	P	P	P	P	P	P	—	P	C	P	—	N	C	—	N	P
purslane, common	C	C	C	C	C	C	—	C	C	C	N	N	C	C	N	P
ryegrass, Italian	C	C	C	C	C	C	—	C	N	C	N	C	P	—	C	C
sowthistles	C	C	C	C	C	C	C	C	C	N	N	N	P	—	N	C
sweetclovers	N	N	N	P	P	N	C	P	P	—	N	N	P	—	N	N
volunteer grains	C	C	C	C	C	P	C	C	P	—	—	C	P	—	C	C
<b>PERENNIAL WEEDS</b>																
bermudagrass (regrowth)	T	T	P	T	P	N	—	N	N	C	N	C	T	N	P	P
bermudagrass (seedling)	C	C	C	C	C	C	—	C	N	N	N	C	P	—	C	C
bindweed, field (regrowth)	N	N	P	T	T	N	—	N	N	P	C	N	T	N	N	T
bindweed, field (seedling)	N	N	—	N	N	N	—	N	N	N	P	N	C	—	N	C
nutsedge, yellow	P	P	C	P	P	N	N	N	N	N	N	N	T	N	N	T

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

- CAR = carfentrazone (Shark EW)
- 13/C = 1,3-dichloropropene / chloropicrin (InLine, Telone C35)
- CHL = chloropicrin (Tri-Clor)
- CLE = clethodim (Select Max)
- DCP = DCPA (Dacthal)
- FLM = flumioxazin (Chateau)
- MEB<sup>2</sup> = methyl bromide\*
- MEP = metam potassium (K-Pam HL)
- MET = metam sodium\* (Vapam HL)
- NAP = napropamide (Devrinol)
- OXY<sup>3</sup> = oxyfluorfen (Goal)
- PAR = paraquat\* (Gramoxone)
- PEL = pelargonic acid (Scythe)
- PEN = pendimethalin (Prowl H<sub>2</sub>O)
- SET = sethoxydim (Poast)

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

<sup>NA</sup> Not applicable

<sup>1</sup> 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://wssa.net/wssa/weed/herbicides/>

<sup>2</sup> For use in nurseries under the quarantine and pre-shipment (QPS) exemption.

<sup>3</sup> For fallow bed use prior to transplanting strawberries.

# HERBICIDE TREATMENT TABLE (7/18)

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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*Not all registered pesticides are listed. The following are listed alphabetically. When choosing a pesticide, consider information relating to environmental impact, resistance management, the pesticide's properties, and application timing. Tank mixes may be necessary to achieve desired control; see the Susceptibility of Weeds to Herbicide Control for information on specific weed control. Always read the label of the product being used.*

## FUMIGANTS

*Note: Fumigants such as those products listed below are a source of volatile organic compounds (VOCs) but minimally reactive with other air contaminants that form ozone.*

A. METHYL BROMIDE\*§ / CHLOROPICRIN\*§  
(Tri-Con 50/50) 300–400 lb See label 0  
COMMENTS: Methyl bromide use is allowed **only in strawberry nurseries** through the quarantine and pre-shipment (QPS) exemption.

B. SEQUENTIAL APPLICATION  
*First, apply one of the following*

- 1,3-DICHLOROPROPENE\*§ / CHLOROPICRIN\*§  
(Telone C35) Label rates See label 0  
(Pic-Clor 60) Label rates See label 0  
(InLine) Label rates (drip) See label 0  
COMMENTS: Effective for control of nematodes, soilborne fungal pathogens, and insects. Use higher rates or impermeable films to improve weed and nematode control. InLine application requires a plastic tarp. One gallon of Telone C35 or InLine weighs 11.2 lb; one gallon of Pic-Clor weighs 12.1 lb.

... or ...

- CHLOROPICRIN\*§  
(Tri-Clor EC) Label rates (drip) See label 0  
COMMENTS: A liquid that diffuses as a gas through soil. Very effective for control of soilborne fungal pathogens and insects. Drip irrigation requires an emulsifier. For shank fumigation, use higher rates or impermeable films to improve weed and nematode control. For drip fumigation the use of VIF will improve both nematode and weed control. One gallon of Tri-Clor EC weighs 13.46 lb.

*Then, 5–7 days after fumigation apply one of the following*

- METAM SODIUM\*§  
(Vapam HL, Sectagon 42) 37.5–75 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 4.26 lb of metam sodium.

... or ...

- METAM POTASSIUM\*§  
(K-Pam HL) 30–62 gal See label 0  
COMMENTS: Water-soluble liquid that decomposes to a gaseous fumigant (methyl isothiocyanate). Efficacy affected by soil texture, moisture, temperature, and percent organic matter. One gallon of product contains 5.8 lb of metam potassium.

## PREPLANT HERBICIDES

A. FLUMIOXAZIN 0.0956 lb a.i.  
(Chateau SW) 3 oz 12 0  
WSSA MODE-OF-ACTION GROUP NUMBER: 14  
COMMENTS: Apply a minimum of 30 days before transplanting and before the plastic mulch is laid; plant strawberries through the plastic mulch.

B. OXYFLUORFEN 0.25–0.5 lb a.i.  
(Goal 2XL) 1–2 pt 24 0  
(GoalTender) 0.5–1 pt 24 0  
WSSA MODE-OF-ACTION GROUP NUMBER: 14



Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
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Comments: For fallow bed use prior to planting strawberries. If applied in fields where drip fumigation will be done, apply after beds are formed but before tarps are installed. Apply at least 30 days before transplanting for effective control of little mallow (cheeseweed) and filaree, which are not controlled well by the fumigants. To prevent injury to strawberry plants, do not use unless a plastic mulch will be installed at the time of strawberry transplanting.

C. PELARGONIC ACID (Scythe) WSSA MODE-OF-ACTION GROUP NUMBER: 26 COMMENTS: Good for controlling weeds in furrows when fumigation is planned.	3–5% volume/volume	12	0
D. PENDIMETHALIN (Prowl H2O) WSSA MODE-OF-ACTION GROUP NUMBER: 3	1.5–3.0 pt	24	35

**ESTABLISHED WEEDS**

A. CAPRYLIC AND CAPRIC ACIDS (Suppress)# MODE OF ACTION: A fatty acid that disrupts a plant’s waxy cuticle and cell walls, causing dehydration. COMMENTS: Apply to germinated weeds before crop planting and to furrows using shields to prevent contact with crop plants. Avoid windy conditions. Do not allow contact with strawberry plants, as injury will result. Use ground application; use highest rate for larger weeds.	3–9% volume/volume	24	0
B. PARAQUAT* (Gramoxone SL 2.0) WSSA MODE-OF-ACTION GROUP NUMBER: 22 COMMENTS: Apply as a directed spray to the furrows using shields to prevent contact with crop plants. Avoid windy conditions. Use a nonionic surfactant or crop oil. Do not allow contact with strawberry plants as injury or excessive residues may result. Ground application 20 gal water/acre. Do not apply more than three times per season.	0.50 lb a.i. 2 pt	24	21

**POSTPLANT**

*Before weeds emerge*

A. DCPA (Dacthal Flowable) WSSA MODE-OF-ACTION GROUP NUMBER: 3 COMMENTS: For new plantings apply 12 pt/acre; for established plantings apply 8 to 12 pt/acre in late summer or early fall. Do not apply from first bloom through harvest. Must be applied as banded applications over the rows. Applications can be made over strawberry plants without injury. Does not control emerged weeds.	6–9 lb a.i. 8–12 pt	12	See comments
B. FLUMIOXAZIN (Chateau SW) WSSA MODE-OF-ACTION GROUP NUMBER: 14 COMMENTS: Apply with shielded or hooded sprayer to furrows only; do not apply over strawberry plants. Do not apply after fruit set.	0.0956 lb a.i. 3 oz	12	See comments
C. NAPROPAMIDE (Devrinol 50DF) WSSA MODE-OF-ACTION GROUP NUMBER: 15 COMMENTS: May be applied to newly transplanted and established crop. Do not apply after first bloom. May inhibit runners. Good for controlling weeds in the furrows following drip fumigation.	2–4 lb a.i. 4–8 lb	24	See comments

*After weeds emerge*

A. CAPRYLIC AND CAPRIC ACIDS (Suppress EC)# MODE OF ACTION: A fatty acid that disrupts a plant’s waxy cuticle and cell walls, causing dehydration. COMMENTS: Apply as a directed spray to the furrow bottoms using shielded sprayer to prevent contact with strawberry plants. Avoid windy conditions. Use highest rate for larger weeds.	3–9% volume/volume	24	0
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Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
B. CARFENTRAZONE-ETHYL (Shark EW) WSSA MODE-OF-ACTION GROUP NUMBER: 14	0.096 lb a.i. 6.1 fl oz	12	0
C. CLETHODIM (Select Max) WSSA MODE-OF-ACTION GROUP NUMBER: 1 COMMENTS: Apply for control of annual grasses including annual bluegrass. For repeat applications, the minimum interval between applications is 14 days. Include 0.25% volume-by-volume non-ionic surfactant (NIS) in the finished spray mix.	0.09–0.12 lb a.i. 12–16 fl oz	24	4
D. PARAQUAT* (Gramoxone SL 2.0) WSSA MODE-OF-ACTION GROUP NUMBER: 22 COMMENTS: Apply as a directed spray to the furrow bottoms using shields to prevent contact with crop plants. Avoid windy conditions. Use of a non-ionic surfactant or crop oil is recommended. Do not allow contact with strawberry plants as injury or excessive residues may result. Ground application 20 gal water/acre. Do not apply more than three times per season.	0.50 lb a.i. 2 pt	24	21
E. PELARGONIC ACID (Scythe) WSSA MODE-OF-ACTION GROUP NUMBER: 26 COMMENTS: Good for controlling weeds in furrows following fumigation.	3–5% volume/volume	12	0
F. SETHOXYDIM (Poast) WSSA MODE-OF-ACTION GROUP NUMBER: 1 COMMENTS: Grass weed size is critical for control but varies with species; see label. Only one application allowed per season. Not for aircraft application.	up to 2.5 pt	12	7

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

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

# Acceptable for use on organically grown produce.

<sup>1</sup> 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://wssa.net/wssa/weed/herbicides/>

## 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 <https://globalmrl.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.

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