Crop Profile for the California Containerized Nursery Industry

Revised: May, 2002

General Production Information

In 1997, nursery products ranked 3rd in the state among agricultural commodities with a value of $1.8 billion (CDFA, 2000). California is the leading producer of nursery and greenhouse products in the United States (Economic Research Service, USDA, 1999) and is the most important nursery production state (by percent of U.S. receipts) in the U.S., producing 20% of the nursery crops followed by Florida (11%), North Carolina (8%), Texas (8%), and Ohio and Oregon (5% each) (Economic Research Service, USDA, 1999). In 1997, outdoor nurseries in California occupied 21,643 acres (Economic Research Service, USDA, 1999). The net sales value in of the crop in 1997 was $6.6 million. Aside from capital costs such as land and equipment, and buildings and costs associated with transportation of the product, production costs include labor, fertilizer and pesticides, pots, propagative material, potting mix, pots and labels. To be successful, nurseries must operate on a gross profit margin of 30% or better (California Association of Nurserymen, 1999).

Production Regions

Most nurseries are located on the coastal regions of California due to the mild climate. Because freezing temperatures rarely impact these regions, plants can be produced and sold year round. Also, because there is little need to protect plants from low temperatures, most nursery stock (over 80%) is grown in containers (Schuch and Klein, 1996). The top producing counties in California in 1997 (latest data available) are San Diego, Los Angeles, Orange, San Mateo, and Ventura (CDFA, 1998).

Cultural Practices

Outdoor grown nursery crops are predominantly grown for sale to retail nurseries and then to consumers for landscaping. There may also be direct sales to commercial landscapers and some nurseries operate both wholesale and retail businesses. Commercial nurseries may also produce stock for commercial fruit and nut plantings. However, for the purposes of this evaluation, only outdoor grown containerized ornamental plants are covered.

Individual nurseries may produce more than 1000 different species of plants (Schuch and Klein, 1996) and plants are grown for sale year round. Because of the constant demand for plants, nursery products can be found in varying stages of growth in a nursery. In addition, plants are sold in different sizes depending on the customer’s needs. In general, woody shrubs are sold in 1, 3, or 5-gallon containers while trees are sold in 10 or 15-gallon pots or larger boxes. Depending on the type of plant and desired size, an individual plant may be sold as soon as 1 month from transplanting to as long as 3 years. Generally, only large trees, topiary types, or very slow growing plants stay in a nursery for 3 or more years. Most 1-gallon plants are shipped in 1-6 months and 5-gallon plants in 2 months to 2 years. Because production is year round and there is a diversity of plants grown in each nursery, there is always a lot of human activity in the production areas, including pruning plants, moving containers, watering, applying pesticides, and scouting for pests.

Nursery crops are usually grown from liners. These are vegetatively propagated plants grown in a protected area such as a greenhouse or shade house in small (2-4") pots. Unless the species is very vigorous, liners are transplanted into 1-gallon
containers. After the plant is established, it can either be sold or transplanted into progressively larger containers. Plants in larger containers are sold at higher prices to recover the additional cost of labor, materials, and time in the nursery. Containers are set on woven nursery mat to reduce the growth of weeds around the containers. Gravel may be used in place of or over the mat.

Most containerized plants are grown in either a soilless mix or one containing only a small amount of soil. Soilless potting mixes may contain peat moss, sand, sawdust, bark, compost, or other materials in varying percentages depending on how the mix is to drain and its weight. Drainage is important because there is no buffering of water amounts in the container; if the mix remains wet for too long a period, plants become more susceptible to root diseases. If it drains too quickly, the plants must be irrigated more often or else they will wilt and die. The weight of the potting mix is important because of shipping costs and because the containers are regularly moved to change spacing or fill in an area after a section is sold.

Fertilizing is accomplished by incorporating a quick release fertilizer in the potting mix prior to transplanting. This is supplemented with regular fertilization through the irrigation system or by using a slow-release top dressing of fertilizer. The slow-release fertilizer can also be incorporated into the potting mix prior to transplanting.

Plants must be irrigated to maintain good growth. One-gallon containers are irrigated using impact sprinklers and larger containers are watered using impact sprinklers, drip, or microsprinklers. In smaller nurseries and where needed in larger nurseries, irrigation is supplemented with hand watering. Water not taken up by the plants or drained into the soil can be directed to run off into recycling ponds, into other areas that have plants that can be sub-irrigated, or off the property. While the cost of water varies in the production regions, even if water is relatively cheap, runoff is avoided because it is difficult to work in wet areas.

Pests are controlled by various methods. Weeds are hands-picked from containers prior to regular applications of preemergent herbicides. Disease control is accomplished by preventative treatments of fungicide applied as a soil drench or spray. Less often, fungicides are used as curative treatments. Generally, when a plant shows symptoms of disease, it is culled and discarded. Insects are controlled primarily by insecticides and less often by pruning or other method. In 1997, nearly 156,149 pounds of pesticide (active ingredient) was used in outdoor ornamental plant production in the top five nursery production counties (CDPR 1997 Pesticide Use Reports). Twenty-seven pesticides accounted for 85% of all active ingredients by weight (Table 1).

Table 1. Number of applications and pounds of active ingredient of the most heavily used pesticides\(^1\) used for outdoor ornamental plant production (does not include cut flowers) in Los Angeles, San Diego, Ventura, San Mateo, and Orange Counties in 1997 (CDPR, 1997 Pesticide Use Reports).

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Type</th>
<th>#applications</th>
<th>lb. a.i.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>Fungicide</td>
<td>613</td>
<td>3,516.33</td>
</tr>
<tr>
<td>Copper hydroxide</td>
<td>Fungicide</td>
<td>868</td>
<td>2,396.71</td>
</tr>
<tr>
<td>Fosetyl-al</td>
<td>Fungicide</td>
<td>598</td>
<td>7,528.11</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>Fungicide</td>
<td>680</td>
<td>3,587.91</td>
</tr>
<tr>
<td>Metalaxyl</td>
<td>Fungicide</td>
<td>1,953</td>
<td>1,426.19</td>
</tr>
<tr>
<td></td>
<td>Category</td>
<td>Quantity</td>
<td>Unit Price</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>----------</td>
<td>--------------</td>
</tr>
<tr>
<td>PCNB</td>
<td>Fungicide</td>
<td>153</td>
<td>2,803.71</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Fungicide</td>
<td>133</td>
<td>3,316.67</td>
</tr>
<tr>
<td>Thiophanate-methyl</td>
<td>Fungicide</td>
<td>1,519</td>
<td>5,292.53</td>
</tr>
<tr>
<td>Iprodione</td>
<td>Fungicide</td>
<td>758</td>
<td>1,748.58</td>
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<tr>
<td></td>
<td><strong>Total fungicide</strong></td>
<td></td>
<td><strong>31,616.74</strong></td>
</tr>
<tr>
<td>Methyl bromide</td>
<td>Fumigant</td>
<td>52</td>
<td>6,951.10</td>
</tr>
<tr>
<td></td>
<td><strong>Total fumigant</strong></td>
<td></td>
<td><strong>6,951.10</strong></td>
</tr>
<tr>
<td>Diquat dibromide</td>
<td>Herbicide</td>
<td>736</td>
<td>3,539.05</td>
</tr>
<tr>
<td>Glyphosate, isopropylamine salt</td>
<td>Herbicide</td>
<td>3,048</td>
<td>18,976.59</td>
</tr>
<tr>
<td>Oryzalin</td>
<td>Herbicide</td>
<td>1,290</td>
<td>5,224.69</td>
</tr>
<tr>
<td>Oxyfluorfen</td>
<td>Herbicide</td>
<td>403</td>
<td>3,302.67</td>
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<td>Pendimethalin</td>
<td>Herbicide</td>
<td>712</td>
<td>3,416.37</td>
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<td>Prodiamine</td>
<td>Herbicide</td>
<td>305</td>
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<tr>
<td>Simazine</td>
<td>Herbicide</td>
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<td>1,746.49</td>
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<tr>
<td></td>
<td><strong>Total herbicide</strong></td>
<td></td>
<td><strong>37,869.29</strong></td>
</tr>
<tr>
<td>Acephate</td>
<td>Insecticide</td>
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<td>4,844.68</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Insecticide</td>
<td>171</td>
<td>1,209.16</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Insecticide</td>
<td>916</td>
<td>1,483.66</td>
</tr>
<tr>
<td>Diazinon</td>
<td>Insecticide</td>
<td>870</td>
<td>1,569.90</td>
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<tr>
<td>Malathion</td>
<td>Insecticide</td>
<td>1,362</td>
<td>4,273.11</td>
</tr>
<tr>
<td>Petroleum distillates, refined</td>
<td>Insecticide</td>
<td>431</td>
<td>7,535.81</td>
</tr>
</tbody>
</table>
Petroleum oil, unclassified | Insecticide | 795 | 19,354.38
Potash soap | Insecticide | 388 | 7,807.98
Methiocarb | Insecticide/ Molluscicide | 162 | 1,034.15

Total insecticide | 49,112.81
Metaldehyde | Molluscicide | 875 | 7,244.47

Total molluscicide | 7,244.47

Grand total | 132,794.42

1Does not include surfactants, adjuvants, or alcohol products

In 1999, all nurseries in Orange County were placed under quarantine for red imported fire ant (RIFA). As a result, all nursery material with soil leaving the quarantined area must be treated with insecticides identified by the California Department of Pesticide Regulation and California Department of Food and Agriculture to control RIFA. These include products containing chlorpyrifos (organophosphate), diazinon (organophosphate), bifenthrin (pyrethroid), and fenoxycarb (insect growth regulator). The mandated use of these materials resulted in an increase in the first three materials in Orange County from 677, 683, and 46 pounds of active ingredient, respectively, in 1997 to 49900, 1109, and 660 pounds, respectively, in 1999 (CDPR 1999 Pesticide Use Reports) (Figure 1).

Figure 1. Pounds of active ingredient of chlorpyrifos, diazinon, and bifenthrin used in Orange County, California in 1997 and 1999.

We surveyed nurseries in Orange, Los Angeles, Fresno, Visalia, and San Diego regarding what their major pests were and how they controlled them. From the surveys, we extracted the top 5 pests for each category and report on them below.

Summary of Survey results:

1. Counties included in survey
2. Size of production (acres)

<100 20%

>100 80%

3. Costs of

<table>
<thead>
<tr>
<th>Cost</th>
<th>Average cost per month for 100 acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scouting</td>
<td>$ 1,100</td>
</tr>
<tr>
<td>Pesticide application</td>
<td>$ 7,000</td>
</tr>
<tr>
<td>Pesticide materials</td>
<td>$ 7,500</td>
</tr>
</tbody>
</table>

4. Pest Control

**Insects/Mites:** Growers were asked to rank arthropod pests in order of the amount of pesticide used to control them. For growers inside the quarantine zone, the red imported fire ant was ranked as number one for all growers. Other pests that consistently ranked in the top ten for pesticide use were aphids, mites, whiteflies, mealybugs, scales, thrips, and lepidoptera. Details about these pests and their control are described in the section on Insect and Mite Control. Subsequent to the initial release of this report, glassy-wing sharpshooter was classified as a quarantine pest in the southern half of the state. Consequently, that pest is now a major issue for growers due to treatment and inspection regulations involving this insect.

**Weeds:** Growers were asked to rank weeds in order of the amount of pesticide used to control them. Weeds that were consistently ranked in the top ten for pesticide use were common groundsel, bittercress, oxalis, prostrate spurge, liverwort, and moss. Details on these weeds are described in the section on Weed Control.

**Disease:** Growers were asked to rank diseases in order of the amount of pesticide used to control them. Diseases that were consistently ranked in the top ten for pesticide use were damping off (*Pythium, Rhizoctonia*), *Phytophthora* root rot, powdery mildew, downy mildew, bacterial leaf spot, and fungal leaf spot. Details on these diseases are described in the section on Disease Control.

5. Other Important issues.
### Exotic Pests
- Red imported fire ant
- Whiteflies
- Effects of pesticides on non-target pests

### Pesticide Runoff
- Runoff during storms
- Chlorpyrifos, diazinon runoff
- Confusion over criteria for toxicity levels and limits in water moving offsite
- Maintaining clean well water

### Ag-Urban Issues
- Neighbor complaints
- Vandalism
- Notification of neighbors
- Urban encroachment (schools, houses)
- Effects of pesticides on the environment
- Nitrate runoff

### Other
- Availability of registered materials
- FQPA = loss of registered materials
- Public perception of pesticide danger
- Amount of pesticide used
- Restriction or removal of pesticides from horticulture

6. Other pests:
- Birds
- Squirrels
- Gophers
- Raccoons
- Rabbits
Rats/Mice

7. Average Rating of factors from highest to lowest (5=most important, 0=not important)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide cost</td>
<td>4.8</td>
</tr>
<tr>
<td>Pesticide and fertilizer runoff</td>
<td>4.7</td>
</tr>
<tr>
<td>Environmental regulations</td>
<td>4.3</td>
</tr>
<tr>
<td>Training or education regarding pests, pesticides, integrated pest management</td>
<td>4.3</td>
</tr>
<tr>
<td>Pesticide availability</td>
<td>4.0</td>
</tr>
<tr>
<td>Scheduling of pesticide application</td>
<td>4.0</td>
</tr>
<tr>
<td>Availability of low risk pesticides</td>
<td>4.0</td>
</tr>
<tr>
<td>Water recycling</td>
<td>3.7</td>
</tr>
<tr>
<td>Labor cost</td>
<td>3.0</td>
</tr>
<tr>
<td>Labor availability</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Insect Pests

The following section gives short descriptions of some of the most common arthropod pests found in nursery production systems. Portions of this section were compiled from University of California IPM Pest Management Guidelines: Floriculture and Ornamental Nurseries (UC DANR Publication 3392) and Integrated Pest Management for Floriculture and Nurseries (UC DANR Publication 3402). For more detailed information and color photographs of these and other pests, see these publications. For details on chemical control options for these pests see the University of California IPM Pest Management Guidelines website at [http://www.ipm.ucdavis.edu/PMG/selectnewpest.floriculture.htm](http://www.ipm.ucdavis.edu/PMG/selectnewpest.floriculture.htm).
Insect and Mite Control  All growers inside the quarantine zone ranked red imported fire ant as their number one pest. Other pests that consistently ranked in the top ten for pesticide use were aphids, mites, whiteflies, mealybugs, scales, thrips, and lepidoptera. Details about these pests and their control are described below.

ANTS

Native and Imported Fire Ants – *Solenopsis invicta*, *S. xyloni*, *S. aurea*, others

**Description of Pests:** All fire ants belong to the genus *Solenopsis* and are characterized by having a 2-segmented petiole (the narrow waist between the thorax and abdomen), 10-segmented antennae with a 2-segment club, and a stinger. There are two native fire ant species likely to be encountered in California and confused with the red imported fire ant or RIFA. The more common one, the southern fire ant (*Solenopsis xyloni*), 2.5-4.5 mm in length, is found in coastal and inland regions. It is very similar in appearance to the RIFA. Besides technical differences in the shape of the clypeus requiring the use of a hand lens or microscope, the southern fire ant differs from the RIFA in that it is bicolored, with a reddish head and thorax and a dark brown abdomen. By contrast, the RIFA is an almost uniform dark reddish-brown and 3-6 mm long. Furthermore, the southern fire ant mounds are irregular craters, whereas the RIFA mounds are frequently built up into domes. *S. aurea* is almost entirely yellowish and is largely limited to the Colorado Desert in California. All three species are polymorphic, i.e., the workers are of mixed sizes. Another characteristic difference between these species is the aggressiveness of the workers. Although they will all sting, the ferocity of the RIFA is notable. Any object touching their mound is immediately attacked and stung and the workers will quickly run up a stick that touches the mound.

**Damage:** RIFA pose an immediate threat to the area’s economy because they require a quarantine of nursery products. In quarantined areas plants cannot be shipped without labor-intensive and expensive drenching of all plants with pesticides. Furthermore, the ants indirectly impact many plants and crops because they tend and protect plant pests such as aphids and scale insects. They also chew on soft plant tissue and growing buds. Their stinging behavior can be hazardous to field workers. Newborn livestock and poultry are vulnerable to attack. They can clog irrigation lines and short-circuit electrical systems. In natural ecosystems they interfere with and displace native wildlife. Their sting is noxious and produces a pustule on the skin that can scar if it gets infected. Due to their pervasiveness in infested areas, they can degrade the quality of life. Hunters, hikers, and campers have to modify their outdoor activities so as to avoid stepping on ant mounds.

**Biology:** The RIFA originally introduced in the southeast, was described as having one queen per mound, or ‘monogyne’. Colonies of this type are highly territorial and will fight with neighboring colonies. However, the predominant form in Texas has become the ‘polygyne’ form, meaning that there are many queens per colony. The polygyne fire ant can have hundreds of mounds per acre compared with the 30-40 typical for the monogyne form. Many of these mounds are connected underground so that brood and queens can quickly move between them. Polygyne ants are not territorial and can frequently mix with little fighting. Researchers have shown that the total egg production for the multiple queens exceeds that of the single queen in a monogyne colony. Thus, there are more mounds and more ants per acre in polygynous ants. Polygyne ant colonies can reproduce by budding, where some of its queens and workers advance to a new location. This process allows them to saturate a field in a relatively short time.

It is still uncertain whether the RIFA in the nurseries are monogyne or polygyne. This could have a significant impact on the effectiveness of baiting treatments.

**Biological Control:** The USDA and the University of Texas have begun the first biocontrol program to control fire ants. There is a tiny South American fly, called a phorid that is a natural parasite of fire ants. It lays its egg in the neck region of the worker ant. The larva that hatches from this egg eventually consumes the ant’s brains and causes the ant’s head to drop off. The new fly then emerges from the head of the ant. These flies are being mass reared and released in Florida and Texas. Researchers are also investigating other parasitic insects and even protozoa from South America.

**Monitoring:** Presently, monitoring stations baited with Spam meat are being used at 50-ft intervals to monitor for the presence of RIFA in nurseries.
Chemical Control for Fire Ants in Quarantine Areas: In quarantine fire ant situations the USDA has approved a number of products with differing certification periods. Chlorpyrifos drenches of plants provide 30 days of certification. The longest certification is given to incorporation of Talstar® granules (pyrethroid, bifenthrin) into potting soil. The USDA certifies these treatments for 180 days. The California Department of Food and Agriculture recommends soil incorporation of the Talstar, plus treatment of the infested grounds with ant baits. Some ant baits, such as Distance and Award, contain IGRs (insect growth regulators) that reduce fire ant numbers in about 6 weeks. Others, such as Amdro (hydramethylnon) can show significant effects in several days, especially reducing the number of workers.

Alternatives: Alternatives for fire ant control are limited by quarantine regulations. Improvement of monitoring techniques to detect ants in infested areas more accurately may allow spot treatment of materials rather than treatment of all containers. Use of bait materials in stations rather than broadcasting or drenching could reduce worker exposure and risk of environmental contamination.

Argentine Ant - Linepithema humile

Description of Pest: The Argentine ant, Linepithema humile (Mayr) (=Iridomyrmex humilis), is a small shiny, brown ant with a one-segmented petiole, and one size worker. Workers are about 2.2-2.6 mm in length and don’t sting. Linepithema humile is found throughout most of southern and central California. Argentine ants are difficult to control because they are polydomous, meaning that individual colonies of ants over a large area are actually interrelated and individual ants can easily move from one nest site to another if a colony is disturbed, and polygynous, colonies having many queens. Mating typically occurs in the nest and colonies spread by budding.

Damage: Argentine ants are the most important ant pest in agriculture and urban areas throughout California. Linepithema humile infestations are a widespread problem for the nursery industry because infested container plants can result in delay or rejection of inter-regional shipments due to quarantines presently in place for RIFA (Solenopsis invicta) and other pests. Argentine ants tend colonies of homopteran pests such as aphids, scales, and whiteflies. They collect honeydew as a food source and actively interfere with natural enemy activity against homopteran pests resulting in larger populations of pests when ants are present. Linepithema humile is also extremely important because they will displace other ants and arthropods disrupting natural ecosystems. This is especially important in newly developing urban areas in riparian habitats.

Biological Control: Currently there are no biological methods of controlling L. humile. Some research is being conducted with phorid flies that appear to alter the foraging behavior of Argentine ants in Brazil, but it is unlikely that these flies could significantly reduce ant populations.

Monitoring: Argentine ants are effectively monitored with bait stations containing sugar water. Visual estimates or the amount of sugar solution consumed can be used to provide an index of foraging activity.

Alternatives: Protein baits containing hydramethylnon and fipronil (MaxForce FG) and liquid sugar baits containing boric acid are commercially available for Argentine ant control. The protein baits are generally more effective when applied in the spring and early summer. Ants typically ignore protein baits in the late summer. Consumption of the various commercially available boric acid baits is sporadic and it may take up to 8 weeks to achieve noticeable control. Studies are being conducted on the potential use of Beauveria bassiana (entomophthogenic fungus) for ant control.

Chemical Controls: Survey results report common materials presently used for ant control in nurseries include diazinon (65%), chlorpyrifos (50%), malathion (15%), and cyfluthrin (15%). Other materials such as acephate, bifenthrin, and baits containing pyriproxyfen, hydramethylnon, and several pyrethroids are also presently registered for use on ants in nurseries.

APHIDS
Melon aphid - *Aphis gossypii*

Green Peach aphid - *Myzus persicae*

Description of Pest: Aphids are distinguished from other insects by the presence of cornicles, tube like appendages that protrude from the rear of the aphid. There are numerous species of aphids attacking California ornamental crops. The two species that are most commonly encountered are the green peach aphid, *Myzus persicae* and the cotton or melon aphid, *Aphis gossypii*. Melon aphids are typically dark green, but color variations do occur frequently. The cornicles are relatively short, stout and always dark. Melon aphids have red eyes and antennae, which only reach to the middle of the abdomen. Green peach aphid is characterized by a depression in the front of the head between the antennae and by long thin, translucent cornicles which extend beyond the tip of the body. Green peach aphids vary in color from yellowish green to rose pink. Winged adults have a dark blotch in the middle of the abdomen. Adult aphids may or may not have wings. Winged aphids arise as a result of crowding. Green peach aphids produce winged adults at lower population densities than the melon aphid. The optimal temperature for GPA development is 75°F whereas optimal temperatures for melon aphids are above 75°F. Adult aphids give birth to living young. Generally, aphids begin giving birth in 7-10 days, depending on temperature.

Damage: Aphids excrete copious amounts of honeydew, causing the plants to become sticky. Sooty molds then grow on the honeydew causing plant parts and areas under the plants to become blackened. As they molt, aphids shed their skins. These white cast skins become stuck to plant surfaces, and also detract from the plant's aesthetics. Sufficient feeding can cause foliage to become yellowed, and feeding on newly developing tissues will cause those parts to become twisted as they grow. Melon aphids are known to transmit 44 plant viruses, while green peach aphids are known to transmit more than 100 plant viruses.

Biological Control: Predators such as lacewings (*Chrysoperla* spp.) and midges (*Aphidoletes aphidimyza*) are commercially available. Parasitoids, such as *Aphidius* spp., *Lysiphlebus testaceipes*, *Diaeretiella rapae*, and *Aphelinus abdominalis*, are also commercially available.

Cultural Control: Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for aphid populations. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 355 microns or smaller. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of aphids and other pests, and disinfested if needed.

Monitoring: Yellow sticky cards placed in greenhouses will capture winged adults. However, aphids produce winged individuals in response to crowding so scouting for infestations is an essential component of monitoring. Melon aphids also tend to have a more uniform vertical distribution on plants than green peach aphids which tends to be clustered around growing points, meaning that infestations of melon aphids under lower leaves can easily go undetected.

Chemical Control: Survey results report common materials presently used for aphid control in nurseries include the organophosphates malathion (50% of growers), acephate (80% of growers), chlorpyrifos (15%), and diazinon (15%); synthetic pyrethroids cyfluthrin (15%), fluvinate (15%), bifenthrin (15%), rotenone/pyrethrin (15%); the carbamate methiocarb (15%); a neem extract azadiractin (15%), paraffinic oils (30%), and potash soaps (15%). See appendix for detailed listings of these and additional registered materials.

WHITEFLIES

Greenhouse Whitefly - *Trialeurodes vaporariorum*

Description of the Pest: The greenhouse whitefly adult is 0.9 (male) to 1.1 mm (female) long, with four wings, sucking mouthparts, and a powdery waxy coating over the body and wings that give the otherwise yellow body a white color. The
wings are held nearly parallel to the leaf and cover the abdomen when the adult is at rest. There are six life stages: egg, four instars, and the adult. Females lay eggs in circles on the undersides of leaves of plants with smooth leaves; on plants with pubescent leaves, the eggs may be more scattered. Eggs are partially inserted into the leaf, initially they are yellowish, but close to hatching they turn a purplish brown. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the underside of the leaf and do not move. The end of the fourth instar is called a pupa. The pupal stage is the most important for whitefly species identification. Greenhouse whitefly pupae are oval and have vertical sides, giving the pupa a cake-like appearance from the side. Along the perimeter of the upper surface there is a fringe of filaments, there are also much larger wax filaments projecting above the upper surface of the body. The greenhouse whitefly can complete one generation in 21 to 26 days at 81ºF.

**Silverleaf Whitefly - Bemisia argentifolii**

**Description of the Pest:** The silverleaf whitefly adult is 0.8 (male) to 1.0 mm (female) long, with four wings, sucking mouthparts. In contrast to the greenhouse whitefly, the silverleaf whitefly has limited amounts of waxy coating over the body and wings that give the otherwise yellow body a whitish hue. The wings are held at the sides of the body, partially exposing the back of the abdomen when the adult is at rest. There are six life stages: egg, four instars, and the adult. Eggs are not laid in a circular pattern, are partially inserted into the leaf, and they remain yellowish until they hatch. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf and do not move. The end of the fourth instar is called a pupa. Silverleaf whitefly pupae are ovoid, but with a slightly pointed hind end and red eye spots easily visible from above. The pupa is convex and does not have a marginal fringe of filaments. The length of wax filaments projecting above the upper surface of the body varies on different hosts. Silverleaf whiteflies can complete development in 16 (86ºF) to 31 (68ºF) days.

**Damage:** Whitefly adults and immatures feed on sap. As they feed, they excrete honeydew, which is unsightly and supports the growth of sooty mold. Very large populations of whiteflies cause stunting of plant growth, and leaves may senesce and die. Physiological abnormalities, such as white stem on poinsettia, may also occur. Usually populations are not so high, and damage is due to honeydew, sooty mold, and nuisance populations of adults.

**Biological Control:** *Encarsia formosa*, a parasitic wasp, has long been recognized as an effective biological control agent for greenhouse whiteflies. Wasps are released at a rate of two to five parasites per plant for 8-10 weeks of the growing season. This sort of release program can be effective if long residual insecticides have not been applied in advance of the parasite release, and where the initial population is quite low (only a few whiteflies per plant). Greenhouse whitefly pupae turn black when parasitized by *Encarsia*. *Encarsia* emerge as adults through circular exit holes. *Delphastus pusillus*, a whitefly predator, has been used against silverleaf whiteflies. *Eretmocerus eremicus* is a commercially available whitefly parasite for silverleaf whitefly.

**Cultural Control:** Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for whitefly populations. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 405 microns or smaller. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of whiteflies and other pests, and disinfested if needed.

**Monitoring:** Yellow sticky cards placed in greenhouses will capture adult whiteflies. However, traps need to be used at a greater density, e.g. 1/1,000 sq. ft. than for other pests. When monitoring plants, it is imperative to look on the undersides of leaves.

**Chemical Control:** Survey results report common materials presently used for whitefly control in nurseries include the organophosphates malathion (30% of growers) and acephate (65% of growers); the fungal pathogen *Beauveria bassiana* (30%); imidacloprid (30%); IGRs pyriproxyfen (15%) and s-kinoprene (15%), pyrethroids cyfluthrin (15%), fluvalinate (50%), bifenthrin (15%); and paraffinic oils (15%) See appendix for detailed listings of these and additional registered materials.
MEALYBUGS

Foliar Feeding Mealybugs

Citrus mealybug - *Planococcus citri*
Madeira mealybug - *Phenacoccus madeiriensis*
Longtailed mealybug - *Pseudococcus longispinus*

Root Mealybugs - *Rhizoecus spp.*

Description of the Pest: These slow moving sucking insects have a loose waxy coating on the body that gives them their mealy appearance. The citrus mealybug is heavily and evenly covered with white, powdery wax, except for a fainter narrow streak down the middle. It has short, wax filaments, along the sides and hind filaments about ¼ the length of the body. Both the citrus mealybug and the Madeira mealybug lay eggs in ovisacs (within masses of cottony wax). The Madeira mealybug can be distinguished from the citrus mealybug by four rows of thin waxed depressions down the back. The longtailed mealybug has four long terminal wax filaments held parallel to the axis of the body, and gives live birth to young. Mealybug infestations often occur underneath foliage, and in difficult to reach cracks and crevices. Root mealybugs are below-ground dwelling mealybugs, feeding on the roots of plants. These mealybugs have a thin, uniform waxy coating and lack the terminal wax filaments typical of their foliar-feeding relatives.

Damage: Mealybugs remove sap from the plants, causing yellowing of leaves and decline. Mealybug ovisacs and the honeydew excreted by mealybugs are unsightly. Honeydew allows the growth of sooty mold fungi and attracts ants, which then carry mealybugs to uninfested plants. The only outward sign of root mealybug feeding may be a decline in the health of infested plants. When plants are removed from the pot, the whitish mealybugs feeding on the roots are then observed.

Biological Control: *Cryptolaemus montrouzieri*, the mealybug destroyer ladybeetle, is an effective predator of citrus and Mexican mealybugs and other ovisac-forming sucking insects, such as green shield scale. Larval mealybug destroyers look like large, faster-moving mealybugs, but are readily distinguished by their chewing mouthparts. *Leptomastix dactylopii*, a parasite of citrus mealybugs, is also commercially available. Effective predators or parasites of longtailed mealybugs are not yet commercially available. Biological control for root mealybugs has not been investigated.

Cultural Control: Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of mealybugs and other pests, and disinfested if needed.

Monitoring: Look for signs of honeydew, including ant activity. Regularly inspect plants. Include root-ball examinations when scouting, and when plants showing decline are observed.

Chemical Control: Survey results report common materials presently used for mealybug control in nurseries include the organophosphates malathion (30% of growers), acephate (50% of growers), and chlorpyrifos (30%); the chloronicotinyl imidaclopid (15%); the pyrethroid fluvalinate (15%); and paraffinic oils (50%). See appendix for a detailed listings of these and additional registered materials.

SCALES

Soft Scales

Brown soft scale - *Coccus hesperidium*
**Hemispherical scale - Saissetia coffeae**
**Black scale - Saissetia oleae**
**Green shield scale - Pulvinaria psidii**

**Description of the Pest:** Soft scales are typically found on woody plants and foliage plants. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf or twig and (with the exception of green shield scale) do not move. These scales typically have a more conspicuous profile from a side view compared with armored scales, and produce copious honeydew. The protective covering of soft scale cannot be separated from its body. Hemispherical scale adults are strongly convex, hard, brown, smooth and shiny. Black scale adults are globular and hardened with ridges in the back that look like the letter "H". Green shield scale, introduced into California approximately in 1992, has a light yellow green color as an immature, then parthenogenetically (without mating, there are no males) produces a mass of eggs in a cottony ovisac.

**Damage:** Soft scales remove sap from the plants, causing yellowing of leaves and decline. Green shield scale ovisacs and the honeydew excreted by all the soft scales are unsightly. Honeydew allows the growth of sooty mold fungi and attracts ants, which then carry scales to uninfested plants.

**Biological Control:** The black scale parasite, *Metaphycus helvolus*, has also been used for control of the closely related hemispherical scale. The mealybug destroyer, *Cryptolaemus montrouzieri*, is known to be an effective predator of green shield scale. Green shield scale, however, is a CDFA "A" rated quarantine pest, so plant material must be entirely free of its presence to be shipped.

**Cultural Control:** Exclusion of wind-blown crawlers can be accomplished by covering openings to the greenhouse with fine-mesh screens. Prune out and discard heavily infested plant parts. New plants should be carefully inspected to ensure that they are free of scales and other pests, and disinfested if needed.

**Monitoring:** Double-sided sticky tape wrapped around infested stems are useful for determining when crawlers are active.

**When to treat:** Optimum treatment timing is when crawlers are active; however, this can be difficult when there are overlapping, multiple generations.

**Armored Scales**

**Oystershell scale - Lepidosaphes ulmi**
**Greedy scale - Hemiberlesia rapax**
**California red scale - Aonidiella aurantii**
**Oleander scale - Aspidiotus nerii**
**San Jose scale - Quadraspidiotus perniciosus**

**Description of the Pest:**

The protective covering over armored scales is produced by molted skins and secretions from the scale. Unlike soft scales, armored scale bodies can be separated from their protective coverings. High populations of these sucking insects give plant stems a crusty appearance. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf and do not move. Unlike soft scales, however, the armored scales do not produce honeydew.

**Damage:** Along with the unaesthetic encrustations, these scales inject toxic saliva that can cause the plants to decline.

**Biological Control:** *Aphytis melinus* is a commercially available parasite effective on California red scale.

**Cultural Control:** Prune out and discard heavily infested plant parts. Exclusion of wind-blown crawlers can be
accomplished by covering openings to the greenhouse with fine-mesh screens. New plants should be carefully inspected to ensure that they are free of scales and other pests, and disinfested if needed.

**Monitoring:** Double-sided sticky tape wrapped around infested stems are useful for determining when crawlers are active. Optimum treatment timing is when crawlers are active; however, this might be difficult when there are overlapping, multiple generations.

**Chemical Control:** Survey results report common materials presently used for scale control in nurseries include the organophosphates malathion (15% of growers), diazinon (30%), acephate (30%), and chlorpyrifos (30%); the pyrethroid fluvalinate (15%); potash soaps (15%) and paraffinic oils (65%). See appendix for detailed listings of these and additional registered materials.

**Glassy-winged sharpshooter-* Homalodisca coagulata**

**Description of the Pest:** Adults glassy-winged sharpshooters (GWSS) are about 1/2 inch (13-14 mm) long and dark brown color. Wings are membranous and translucent, with reddish veins. The insect overwinters as an adult. It begins laying egg masses from late February through May. The year's first generation matures as adults from May through August. The year's second generation begins as egg masses laid from June through September. It is this generation that produces the next year's offspring. Eggs are laid under the surface of the leaf epidermis. The gray colored nymphs are smaller and wingless. There are 5 immature stages. The insect feeds by piercing plant stems and feeding on plant water conducting tissue (xylem). As they feed they excrete a liquid substance that drops to the leaves or the ground below. There appears to be two generations of GWSS per year in California. The GWSS has a broad host range that included many ornamental plant species.

**Damage:** The glassy-winged sharpshooter transmits a bacterial pathogen *Xylella fastidiosa* that grows in the xylem, or water conducting tissue, of certain plant species. *X. fastidiosa* can cause a number of plant diseases in a variety of hosts. Thus far, strains of *X. fastidiosa* that cause oleander leaf scorch, Pierce’s disease of grapevines, almond leaf scorch, and alfalfa dwarf have been identified in California. The strains of the pathogen that infect oleander do not appear to infect grape and are genetically distinct from the other strains.

**Biological Control:** There are no commercial sources of biological control agents for GWSS currently available; however, there is a fairly high level of naturally occurring egg parasitism late in the season.

**Monitoring:** Monitoring methods such as yellow sticky traps, beating samples and visual counts can used to detect the presence of GWSS. Yellow sticky cards should be placed at canopy height at densities not less than 1 card per one-half acre. Check cards at least once a week for adult sharpshooters. Beat or sweep sampling for nymphs and adults is most effective when temperatures are cool (<60 F). Place a white 2-foot square sheet of fabric or other material underneath the canopy to be sampled. Strike canopy with a stick or shake vigorously to dislodge insects for the foliage. Count the number of insects on the sheet. At warmer temperatures the insects will fly away before they can be counted. A sweep net may be also used to sample foliage for the presence of adults and nymphs. Visual inspection of leaves, stems and branches is perhaps the best method for detecting all stages. Insects may try and move to the far side of the stem to avoid detection. Placing a hand close behind the stem being observed will make the insects move to the front where they can be seen. Egg masses can be easily detected by inspecting the undersides of leaves against a sunny sky.

**Quarantine Requirements.** Shipment of nursery stock from infested to non-infested areas within and outside of California can require compliance inspections and/or treatments. A model compliance agreement for shipping plants outside of the quarantine are can be found at: [http://plant.cdfa.ca.gov/gwss/docs/gwrq0331.pdf](http://plant.cdfa.ca.gov/gwss/docs/gwrq0331.pdf).
THRIPS

Western Flower Thrips - *Frankliniella occidentalis*

Greenhouse Thrips - *Heliothrips haemorrhoidalis*

**Description of the Pest:** Thrips adults have four feather-like wings, each consisting of a thick supporting strut with fine hairs on the front and hind edges. Thrips go through six life stages: egg, first instar, second instar, prepupa, pupa, and adult. These thrips insert eggs into the plant tissue. The first two instars and the adults feed by piercing and removing the contents of individual plant cells. Western flower thrips usually feed in enclosed tissues such as flowers, buds, or growing tips. Adults also feed on pollen and on mites. The prepupal and pupal stages take place in the soil beneath the infested plant. Females will lay male eggs if unmated, both sexes if mated. Development times to complete one generation of western flower thrips varies from 11 days (77º - 87ºF), to 44 days (57ºF).

**Damage:** Direct feeding damage includes streaking, spotting, and tissue distortion. Western flower thrips can vector tomato spotted wilt virus. Flower thrips activity can cause premature senescence of flowers because of their pollination activity. On orchids, flower thrips feeding will leave translucent 'pimpling' spots on petals. Greenhouse thrips stipple the foliage of numerous field and greenhouse grown plants. The stippling damage caused by thrips feeding on individual cells is often confused with mite stippling. Thrips feeding is often accompanied, however, by black, varnish-like flecks of frass.

**Biological Control:** Three commercially available predators are the minute pirate bug, *Orius tristicolor*, and two predatory mites, *Neoseiulus cucumeris* and *Hypoaspis* mites. Minute pirate bugs are polyphagous, and will also feed on aphids, mites, and small caterpillars. *Orius* are released at a rate of 2000 to 4000 per acre, while *Neoseiulus cucumeris* are released at a rate of 10 to 50 mites per plant for each of 2-3 weeks. These mites will also feed on spider mite eggs, pollen, and fungi. *Hypoaspis miles* are soil-inhabiting predators, which feed on thrips prepupae and pupae in the soil. These mites are generally released in the soil at planting.

**Cultural Control:** Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for thrips populations. Most commercially available screens have pore sizes slightly larger than the width of the western flower thrips thorax (145 microns), meaning that some winged adults can penetrate these openings. However, covering openings to the greenhouse with fine screens does exclude most thrips. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of thrips and other pests, and disinfested if needed.

**Monitoring:** Blue sticky cards are most attractive to western flower thrips. However, yellow cards are good predictors of WFT populations, are easier to count and are more commonly used for general-purpose insect monitoring.

**Chemical Control:** Most insecticides must be applied at least 2 times, 5-7 days apart, for efficacy against western flower thrips. Survey results report common materials presently used for thrips control in nurseries include the organophosphates acephate (50% of growers), and chlorpyrifos (30%); the pyrethroid fluvalinate (15%); the spinosyn spinosad (100%); and the carbamate methiocarb (15%). See appendix for detailed listings of these and additional registered materials.

LEPIDOPTERA

Armyworms and Cutworms

**Beet armyworm:** *Spodoptera exigua*

**Yellowstriped armyworm:** *Spodoptera ornithigalli*

**Variegated cutworm:** *Peridroma saucia*
**Descriptions of the Pests:** Beet armyworm is the most frequently encountered of the three species listed above. Adults are heavy-bodied moths (wingspread 25 to 28 mm) with a characteristic mustard or orange colored liver-shaped spot narrowly ringed with white on the forewings. The female lays egg masses on the undersides of leaves, covering the eggs with a felt made from her body hairs. The first through the third instar larvae often feed gregariously, skeletonizing the undersides of leaves, or they feed on the insides of buds. Later instars disperse and feed individually, chewing entirely through leaves of flowers. Early instar larvae are small and green, while late instar larval color may be green, brown, black, or gray. In all instars, there are fine lines along the length of the body, with a more conspicuous lateral stripe and a black spot just dorsal to the lateral stripe behind the head. Beet armyworm continually develops during the winter in mild areas and builds up on weeds and cultivated cotton, lettuce, and tomato fields. One generation can take as little as 31 days at 75°F and 24 days at 80°F. Egg to adult generation times can be calculated using a base threshold temperature of 10.5°C and 49 day-degrees C for the egg stage, and a base temperature of 14.5°C and 236 day-degrees C for completion of larval and pupal stages. The pre-ovipositional stage in the adult is an additional one to two days.

The yellowstriped armyworm larvae have a pair of black triangles on the back of most abdominal segments. Some larvae appear nearly completely black when viewed from above. The lateral stripe is bright orange or yellow. The adult (wingspread 38 mm) has a complex and highly contrasting pattern of brown, yellow and white on the front wings.

The variegated cutworm overwinters as a naked pupa in the soil. Adults have a 39 to 54 mm wingspread, with a distinct liver-shaped outline on the front wings. Larvae have yellow or orange spots or a broken longitudinal stripe at the top of the body, which is otherwise gray. Often there is a dark triangle or "W" shaped mark on the top of the eighth body segment.

**Cabbage Looper - Trichoplusia ni**

**Description of the Pest:** Loopers arch their backs as they crawl. Cabbage loopers are light green and usually have a narrow, white stripe along each side and several narrow lines down the back. The dome-shaped eggs are laid singly on the undersurfaces of older leaves. Adult moths have brown, mottled forewings marked in the center with a small, silver figure 8.

**Diamondback Moth - Plutella xylostella**

**Description of the Pest:** When at rest, the adult male moth's wings meet over its back to show three yellow diamonds. The 1-cm long female moths lay minute eggs singly or in groups of two or three on the undersides of leaves. Each female lays an average of 75 eggs. First instars mine leaves, then are external leaf feeders for the remaining three instars. Mature larvae are approximately 1 cm long, are pale green and wriggle actively when disturbed. An openly woven silk cocoon holds the pupa in place under leaves. Development from egg to adult is 29, 16, and 12 days at temperatures of 68, 77, and 87°F, with the greatest survival at 77°F.

**Damage:** Armyworms and cutworms mostly are a concern due to direct damage to flowers, and to aesthetic injury to leaves that would be marketed with the flowers. Presence of late instar larvae in seedling flats can also cause tremendous plant loss. Although, moderate early-season feeding by armyworms on gypsophila may actually increase tillering and yields.

Young cabbage looper larvae feed primarily on the underside of lower leaves, skeletonizing them. Larger cabbage loopers chew entirely through leaves and flowers.

Diamondback moth larvae chew small circular holes in leaves from the undersides, giving the leaves a shot-hole appearance. Very high populations can defoliate plants. Affected flowers include sweet alyssum, stock, candytuft, and wallflower.

**Biological Control:** A number of parasites, both tachinid flies and parasitic wasps, attack lepidoptera larvae and reduce their population growth rate. However, most of these larvae continue feeding through to the last instar, so parasitized larvae will still damage crops. Viruses also do not usually kill the larvae until later instars. *Trichogramma spp* are egg parasites that can be effective against cabbage looper. Diamondback moth is resistant to many insecticides; *Cotesia plutellae*, *Diaedega insulare*, and *Microplitis plutellae* are commercially available for diamondback moth. Applying insecticides other than B.t.
products are likely to exclude parasites.

**Cultural Control:** Because these pests feed on a large variety of plant species, production areas should be kept free of weeds, which can serve as a host. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens. Screens are especially important when lights are used at night in greenhouses to control flowering. Individual seedling flats may also be covered with screens to exclude adults and larvae. Row covers can be a practical measure to exclude moths in field production as long as the mesh prevents entry of adults and the row cover is held above the plant surface to eliminate oviposition through the fabric.

**Monitoring:** Use pheromone traps to determine adult flight activity and mating. This information can be used to time B.t. sprays for young (susceptible) larvae. Use regular visual inspections of plants to detect larvae and their damage.

**Chemical Control:** Survey results report common materials presently used for lepidoptera control in nurseries include the microbial Bacillus thuringiensis (Bt) (30%); the organophosphates malathion (15%), acephate (15% of growers), and chlorpyrifos (30%); the pyrethroids cyfluthrin (15%), pyrethrin (15%), and fluvalinate (15%); the spinosyn spinosad (30%). See appendix for detailed listings of these and additional registered materials.

**MITES**

**Spider Mites**

**Two-spotted spider mite: Tetranychus urticae**

**Description of the Pest:** Spider mites are web-forming mites that pierce plant cells and remove their contents. All spider mites have one body segment and four pairs of legs as adults. Two-spotted spider mite adults, as the name suggests, are yellowish green with two large dark spots on their sides. These mites lay round or onion-shaped eggs, which hatch into six-legged larvae. The subsequent stages, the protonymph and deutonymph stages, are eight-legged as are the adults. Since the entire life cycle can take as little as 8 (77 to 95°F) to 28 (50 to 68°F) days, spider mites have many generations per year.

**Damage:** Removal of cell contents by spider mites changes the color of leaves from green to olive green, then to a dull brown as feeding increases. Undersides of leaves may have many cast skins of mites, and the webbing on foliage is unaesthetic. Plants may become severely stunted when large mite populations are allowed to feed.

**Biological Control:** Many different species of predatory mites are available for use under different conditions. Phytoseiulus persimilis and Galendromus occidentalis have been used to control mite populations in greenhouses and field situations. These predators can reproduce faster than their prey, yet best results have been obtained when they are released into the crop well before the spider mite populations have built up.

**Cultural Control:** Because spider mites feed on a large variety of plants, production areas should be kept free of weeds, which can serve as refugia. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of mites and other pests and disinfested if needed.

**Monitoring:** Scout the crop regularly, as indirect sampling methods (such as sticky cards) are ineffective. Observe the undersides of leaves with a 10X hand lens, and watch for changes in plant foliage characteristic of mite feeding.

**Treatment Comments:** Except as noted, the materials listed only kill active stages of mites, so more than one treatment may be necessary to break the life cycle. Follow label directions regarding reaplication times. If none are specified, try two applications a week apart.
Thread-Footed Mites

**Cyclamen mite - Phytonemus pallidus**
**Broad mite - Polyphagotarsonemus latus**
**Bulb scale mite - Stenotarsonemus laticeps**

**Description of the Pest:** Life stages of these mites are: egg, nymph, pseudopupa, and adult (one less stage than for spider mites). Eggs of the cyclamen mite are ½ the length of the adult, and are smooth ovals. Eggs of the closely related broad mite are distinguishable from cyclamen mite eggs, since they are studded with rows of white pegs on the egg's upper surface. Immature stages are whiter. The hind pair of legs in the adult female are thread-like, while adult males have stout legs for clasping the female. Adult males carry female pseudopupae on their back. As soon as the adult female emerges, they mate. Cyclamen mite is generally found feeding on growing terminals, in buds or unfolding leaflets. Their development is optimal under moderately warm (60º - 80ºF) and high humidity (80 - 90%) conditions. Broad mite is similar to cyclamen mite, but is found more generally on the plant on the undersides of leaves. Mites disperse between plants on air currents and through mechanical transport. These mites can complete one generation in 7 to 21 days, depending on temperature. Female bulb scale mites lay up to 28 eggs. Adults are usually found between the scales of the bulb and the neck region. These mites overwinter in bulbs between the scales, emerging as the leaves grow. They reenter bulbs as they dry in the field. One generation can be completed in approximately 7 weeks under field conditions.

**Damage:** Feeding by cyclamen and broad mites is easily recognized on all hosts because affected leaves become characteristically cupped, dwarfed and thickened, and the internodes are greatly shortened. Broad mite damage occurs more generally over the plant than cyclamen mite damage. Bulb scale mites feeding in developing shoots can cause longitudinal bronze streaks of discoloration, horizontal cracks, distortion, and death of leaves and flowers.

**Biological Control:** *Neoseiulus californicus* and other species of predatory mites have been used for broad mite and cyclamen mite control.

**Cultural Control:** Because these mites feed on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for mite populations. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of pests, and disinfested if needed. Disinfestation can be accomplished by immersing propagation stock in 110.3 ºF water for 30 minutes, or treatment at 100% relative humidity and 110.3ºF for 1 hour. If hot spots of these mites are found in production areas, consider roguing affected plants and treating the surrounding plants.

**Monitoring:** Visually inspect plants for typical damage symptoms as part of a weekly scouting program.

**Chemical Control:** Survey results report common materials presently used for mite control in nurseries include the carboximide hexithiazox (50%); the macrocyclic lactone abamectin(65%); the organochlorine dicofol (50%); the pyrethroids fluvinate (30%) and bifenthrin (15%); potash soap (15%); and paraffinic oils (50%). See appendix for a detailed listings of these and additional registered materials.

**Other Issues for Insect Pests**

The threshold for insect pests on ornamental plants is extremely low. Consumer acceptance at a retail level is one concern. Additionally, because much of the plant material grown in California is shipped to other states, restrictions on shipping material contaminated with insect pests can result in rejection of shipments with any pests found on plants.

Many growers select organophosphate materials to control insect pests in the nursery. This may be due in part to their broad range of activity against the many insect pests that are found in the nursery. In order to reduce the use of organophosphates, it will be necessary to provide a combination of new cultural, biological and chemical options that can effectively control all pests found in the nursery.
Mandatory use of certain chemicals on all containers in quarantine areas to control fire ants and glassy-winged sharpshooters limits ability to reduce risk. Possible methods of reducing overall amounts of insecticides for fire ants in nurseries include improved monitoring techniques to accurately detect the presence of fire ants and allow treatment of infested areas only. The use of bait stations to confine insecticides rather than broadcasting will reduce possible runoff and worker exposure. In addition, baits would reduce the need for broadcast spray and granular applications.

The wide range of plant materials and varieties grown with variable susceptibility to pest pressure may result in treatment of an entire range of crops rather than infested sections only. Scouting of crops on a regular basis can allow early detection of pests and spot treatment of problem areas before they become widespread.

Weeds

Weed Control: Nurseries reported that their top weed problems were oxalis, spurge, common groundsel, bittercress, and liverworts and mosses. The methods of control are summarized in Table 2. Most growers use a regular weed control program that they would regardless of weed spectrum. This usually consisted of a preemergent herbicide combination followed by hand weeding and a non-selective herbicide. Growers vary the preemergent herbicide based on crop sensitivity rather than weeds controlled.

In general, weeds associated with container production are continual problems due to their year-round production of seeds and effective dispersal of seeds. Whenever weeds are found in containers, their value is reduced because these weeds are then be introduced in to the landscape when planted there. A heavy infestation of weeds will reduce plant growth, particularly root growth, by competing for water and nutrients.

Table 2. Summary of grower response to survey. Number indicates the percentage of growers that used a herbicide or other method to control that weed.

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Description: Creeping woodsorrel, *Oxalis corniculata*, and yellow woodsorrel (*O. stricta*) are common weeds found growing in nursery containers. There is also a purple-leafed subspecies, *O. atrapurpurea*. Woodsorrel grows in both full sun and shaded areas that receive adequate moisture. Creeping woodsorrel is a perennial plant that grows in a prostrate manner and forms roots along its stems where nodes contact the soil. Yellow woodsorrel is also perennial but grows in a slightly more upright manner and does not root at the nodes. Flowers of woodsorrel can be found almost anytime during the year but spring is the period of heavy flowering and seed formation. Seed are borne in erect, cylindrical pods. When seed pods mature, they burst open and forcefully expel the seeds, which may land 10 feet or more from the plant. Because seeds are rough, they adhere to surfaces of machinery, containers that may have dirt on the outer surfaces, or clothing. There are about 10 to 50 seeds per pod and a single plant can produce more than 5,000 seeds. Light is required for germination. Optimum seed germination occurs at temperatures between 60° to 80°F, though some germination occurs at lower temperatures. The seeds can germinate any time of year, but most plant establishment takes place in fall.

Damage: Woodsorrel is a major weed in nurseries. As seed pods mature and expel seeds, creeping woodsorrel spreads from container to container. Hand weeding is used extensively to reduce infestations, even though it is expensive.

Biological control: None

Cultural control: The primary methods of managing woodsorrel are to remove the established plant and to try to control the germinating seeds. Continual hand weeding can control seedlings. It is important to remove the weeds before they set seed. When older plants are pulled out, the rootstock often breaks off and remains in the soil and woodsorrel will regrow.
Chemical control: Several preemergence herbicides are available to control germinating seeds in containers, including pendimethalin, oryzalin, oxadiazon, isoxaben, dithiopyr, and combinations of oxyfluorfen and oryzalin, or isoxaben and oryzalin (Snapshot). Burying seeds or covering them with mulch to block their exposure to light prevents germination. Woodsorrel seedlings may grow at the base of plants, where they escape preemergence herbicide treatment or poke through mulches.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control woodsorrel. If the weed was found in the container 43% of the growers used Roundup. Most (86%) used hand weeding in combination with herbicides.

Other methods of control: It is not known how long seeds remain viable in the soil; however, germination is inhibited or stopped when seeds are exposed to moist, warm (97°F) conditions for 30 minutes.

Prostrate spurge (Euphorbia (=Chamaesyce) humistrata) and spotted spurge (Euphorbia (=Chamaesyce) maculata), (Cudney and Elmore, 1999)

Description: Spotted spurge and prostrate spurge are similar to each other but prostrate spurge roots at the nodes. They are identified as some of the worst weeds in container production throughout California. These plants are low-growing annuals that often form a dense mat on the potting media surface. Although there are other plants classified as spurges, for the sake of brevity in the following sections, "spurge" will refer only to spotted and prostrate spurge.

Spurge is a summer annual that produces numerous seeds starting within 5 weeks from germination. Seeds can remain dormant in the soil until conditions are suitable for germination. Seeds that are produced in summer germinate readily whereas those produced in late fall are mostly dormant and won't germinate until spring. Optimal germination is between 75° and 85°F, but the range is 60°-100°F. When moisture is available, germination can occur almost any time of the year. Light is also required for maximum germination, and seeds buried greater than 1/2 inch will not germinate well.

Damage: Spurge can compete with young plants and reduce growth. It also provides habitat for ants and snails and can be an intermediate host for fungal diseases of cultivated crops. Infested areas must be constantly monitored to hand-pull new plants before they produce seed.

Biological control: None

Cultural control: Germination can be reduced by a layer of mulch. Mulches can effectively limit spotted spurge if they prevent light from reaching the seed.

Chemical control: Preemergence herbicides will control spurge if applied before emergence of the weed. These herbicides include pendimethalin, oryzalin, oxadiazon, prodiamine, and isoxaben. There are no selective herbicides that will control spurge once it is established.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control spurge. If the weed was found in the container 57% of the growers used Roundup or Reward. Most (86%) used hand weeding in combination with herbicides.

Common groundsel (Senecio vulgaris), (Ayeni et al. 1999, Wilen et al. 1999)
**Description:** Common groundsel is an early spring weed in most areas, but can grow all year in coastal areas of California. Common groundsel grows well in most shaded areas such as the environment found under the canopy of container plants. Seeds can be produced very quickly and are dispersed easily by wind. Common groundsel can complete its life cycle in as little as 8 weeks. The plant habit is upright and branched. Flowers are produced in an indeterminate fashion. Because the seed is windborne, it is important to control weeds that are found around the nursery as well as those in the containers.

**Damage:** Common groundsel reduces the salability of plants and increases cost of production due to need for control. Infested areas must be constantly monitored to pull new plants before they produce seed.

**Biological control:** None

**Cultural control:** Germination of common groundsel seeds in the containers can be reduced if a layer of mulch is used to reduce the establishment of wind-blown seeds. Mulches can effectively limit common groundsel invasion if the mulch surface dries out quickly.

**Chemical control:** A non-selective herbicide can be used to control weeds surrounding the nursery. However, it is important to control the plants prior to flowering since seeds may still develop on an otherwise incapacitated plant. Preemergence herbicides will control common groundsel if applied before emergence of the weed. Effective herbicides for preemergence control include oxadiazon, oxyfluorfen, napropamide, and isoxaben as well as combinations of herbicides such Rout, XL, and Snapshot that contain these active ingredients.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control common groundsel. If the weed was found in the container 58% of the growers used Roundup or Reward. Most (86%) used hand weeding in combination with herbicides.

**Bittercress (Cardimine spp.)**

(Ayeni et al., 1999)

**Description:** Bittercress is a member of mustard family and can complete its life cycle in as little as 6 weeks. It is a low growing plant (2-6") that prefers growing in shaded, moist conditions, such as those found in shade houses and under the canopy of irrigated plants. Optimal conditions for growth are between 45 and 85°F, good moisture and moderate to high fertility.

The tiny seeds are produced in a thin capsule that shatters upon maturity, forcefully spreading the seeds up to 3 feet away. There are 18-28 seeds in each capsule. Seeds do not have a dormancy period and may germinate immediately. Seeds may be carried in runoff water or moved by water splashing.

**Damage:** Bittercress competes with the crop for water and nutrients. The presence of bittercress in the container reduces salability of crop and increases the chance that the weed will spread to other containers and other areas of the nursery.

**Biological control:** None

**Cultural control:** Because of the short lifecycle of this weed and lack of dormancy of the seeds, it is important to monitor all areas for this weed. Not only should containers be inspected but also areas surrounding containers. Water should not be allowed to flow over this weed when draining since this will spread the seeds. Also, recycled water should be treated or screened to avoid reintroduction of this weed. Irrigation tubes should be wiped before replacing in an uncontaminated contained because seeds could be present on the tubing.
**Chemical control:** Postemergent herbicides can be used to control bittercress in areas surrounding the containers but there is no selective material for use in a container. Preemergence herbicides are effective but care must be taken that the herbicide is applied prior to seed germination. Where bittercress is known to be problem, the herbicide must be applied as soon as possible and reapplied as needed. Over time, this will reduce the bittercress population. Preemergence herbicides effective for controlling bittercress include isoxaben, oxadiazon, and oxyfluorfen.

Growers used preemergent herbicides Rout, Gallery, Surflan, and OH2 to control bittercress. If the weed was found in the container 58% of the growers used Roundup or Reward. Most (86%) used hand weeding in combination with herbicides.

**Liverwort** (*Marchantia polymorpha*) and **Moss** (*Bryum argenteum*)

*(Anon, 1998, Svenson, 2000)*

**Description:** Mosses and liverworts are Bryophytes (non-vascular plants). They do not produce seeds, rather sexual reproduction is by spores. These plants grow in moist areas because they require water for fertilization and, since they do not have a vascular system, they must absorb water through pores in the vegetative portions of the plant. Their reproductive cycle involves alternating gametophyte and sporophyte generations. These weeds can enter the nursery as spores but also can be introduced through vegetative means via contaminated liners. Liverworts produce gemmae (small budlike structures that detach from the parent plant and are vegetative propagules) and are also spread vegetatively by the leafy-like thallus. Moss and liverwort spores can be carried by air and be spread through the nursery.

**Damage:** Liverwort and moss are serious problems in nurseries due to the frequent irrigation schedule and high levels of fertility. These pests reduce root growth and can harbor other pests. High pressure from these weeds can reduce plant growth dramatically.

**Biological control:** None

**Cultural control:** The impact of liverwort and mosses can be reduced through good sanitation such as disinfecting benches when potting and not reusing containers.

Because water is critical to these plants’ reproduction, water management is very important in managing these weeds. Good drainage and less frequent irrigation will reduce the impact of liverwort and moss. Coarse mulches inhibit growth of these weeds because they dry quickly and are not a good substrate for these non-vascular plants.

High N levels (100-200 mg/liter (ppm)) also promote liverwort and moss growth. Therefore, lowering nitrogen rate or using a slower release form may reduce their growth. However, the micronutrients zinc, iron, or copper may control liverwort and mosses but care must be taken to not over apply and reach toxic levels.

**Chemical control:** Regular sanitation with greenhouse disinfectants can kill spores that land on potting areas. There are materials that will kill liverwort and mosses but are not registered in California. For example, a combination of X-77 surfactant and Captan 50W can control of moss in containers. New products that show potential for controlling moss and liverwort are Zero Tol (ZT). This is a general disinfectant that attacks liverwort, mosses, algae, bacteria, and fungi through oxidation. Mogeton is an herbicide currently used in Europe to control liverworts in container nurseries. Another material, Debco’s Liverwort and Moss Control preparation (450g/l dichlorophen) is also in use outside the U.S.

**Combinations of chemical and cultural control:** Svenson (see reference below) conducted a series of experiments to study how irrigation practices interact with other cultural procedures to influence liverwort development. The best treatment for...
Liverwort suppression in this study was a combination of hazelnut shell mulch, and the application of oxadiazon at label rates. This combination provided good suppression for up to 12 weeks provided irrigation was not frequent.

Most growers used hand weeding as the primary method to control liverwort. Herbicides used were prodiamine (29%) and OH2 (14%) for preemergent control and Scythe, Reward, or Roundup (57% total) for postemergent control. Ferrous sulfate, mulching, and compost was also used.

Diseases

**Disease/nematode Control:** Nurseries reported that their top disease problems were damping off, *Phytophthora*, powdery mildew, downy mildew, fungal leaf spot, and bacterial leaf spot. The methods of control of the growers surveyed are summarized in Table 3. Nematodes were not reported to be a problem, probably because plants are grown in soilless mixes. There is no tolerance for diseases because they dramatically reduce the quality of the plant. Additionally, infected plants do not thrive when transplanted into the landscape and often become more susceptible to secondary problems such as insect attack. Diseases associated with container production must be controlled throughout the crop’s growth period. If they are not controlled by the time the plant is sold or if there is the chance the infect plant or plants will infect others, the plants must be destroyed. If this occurs late in the cropping cycle, all of the investment in growing the crop is unrecoverable.

Table 3. Diseases ranked most important to growers and the materials they use to control them. Number indicates the percent of respondents that used this chemical to control the pest.

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Damping-off

Pathogens: *Rhizoctonia solani*, *Pythium* *spp.*, and others

Description: Damping-off is the name given to seedling diseases most often caused by fungi. As the name implies, the disease is associated with damp conditions. *Pythium* is favored by cool, wet conditions while *Rhizoctonia* can cause disease under somewhat drier and warmer conditions. Seedlings rot at soil line and are killed.

Damage: Damping off is a fungal disease that affects roots or shoots of young plants. Most plants do not recover from this disease and must be destroyed. Young plants wither and die and older plants may get brown lesions on the stems near the soil line.

Biological control: *Streptomyces griseoviridis* and *Trichoderma harzianum* are biological controls which have shown some activity in controlling root and stem rots and wilt diseases of ornamental crops caused *Pythium* and *Rhizoctonia*.

Cultural control: Damping-off can be minimized by providing good drainage because these fungal pathogens are favored by moist conditions.

Chemical control: Because there is little chance a plant can be cured of this disease, growers use soil drenches of fungicide at planting or mix fungicide into the potting mix prior to planting. Mefenoxam, fosetyl-Al (*Pythium* only), iprodione (*Rhizoctonia* and *Fusarium*), PCNB, thiophanate-methyl and triflumizole are commonly used for control. Care must be taken when using these materials that resistance does not develop.

One hundred percent of the growers used thiophanate-methyl to control damping off. Fifty-seven percent of the growers also used iprodione and/or mefenoxam. Trichoderma (a biological) was used by 29% of the nurseries. Other materials used were fosetyl-Al (29%), methyl bromide (14%), PCNB (29%) and triflumizole (14%). Other control measures were scouting.
culling, and increasing drainage.

**Downy Mildew**

**Pathogens: Peronospora spp. and others**

**Description:** This fungal disease is named after the downy-like growth that appears on the underside of leaves during sporulation. Downy mildew infections are sometimes angular in shape and delimited by veins. Pale yellow or necrotic areas are sometimes visible from the upper side of the leaf. Water is required for the fungus to infect the plant and the disease only flourishes under high humidity. The disease is also favored by cool temperatures (40-60°F). Spores of the fungus may survive several days under cool, moist conditions. They are airborne and when they land on a susceptible plant and there is free water, germination and infection occurs, generally in 8 to 12 hours. The fungus also produces a sexual spore that can survive dry conditions, which enables the fungus to survive in absence of the host.

**Damage:** Downy mildew affects foliage and causes leaves to have numerous yellow to brown lesions. Plant quality is greatly affected and the plants should be destroyed rather than sold.

**Biological control:** None registered

**Cultural control:** Regularly inspect plants, particularly when cool and wet, for spore masses on undersides of leaves. Avoid using overhead irrigation. Destroy plants with symptoms.

**Chemical control:** Mefenoxam, mancozeb, fosetyl-Al, chlorothalonil, and copper solutions are commonly used as protectants or curatives. Care must be take when using these materials that resistance does not develop.

Growers in the survey reported using copper, fosetyl-Al, mancozeb, mefenoxam, and triadimefon for control.

**Phytophthora Root and Crown Rots**

**Pathogen: Phytophthora spp.**

**Description:** Phytophthora is a fungal soil disease that infects roots and stems of wood plants. Ideal soil conditions for the growth of Phytophthora fungi are wet soils (70% moisture or higher) with temperatures of 59°- 74°F. Phytophthora survives as thick-walled, resistant spores (oospores) in the soil and as mycelium in infected plant tissues. Spores can survive up to 15 months in moist soil in the absence of host plants. Phytophthora in a nursery is generally spread by contaminated potting media or on soil carried on workers shoes, tools, and even from tires that have been in infested area. Phytophthora can also be introduced in contaminated irrigation water.

**Damage:** Phytophthora is a particularly damaging disease because it can infect the roots and stems of older plants. Roots become non-functional and stems rot. Plants become stunted, low in vigor, and appear as if they were water stressed. Foliage yellows and the plant may wilt and die. Aerial portions of the plant can also be infected by splashing soil containing Phytophthora spores or mycelium.

**Biological control:** No commercial material available.

**Cultural control:** Good drainage and water management is essential to control Phytophthora. Because Phytophthora species
are common in surface waters recirculated must be tested or not used on plants that are susceptible to *Phytophthora*.

**Chemical control:** Mefenoxam, fosetyl-Al, iprodione, PCNB, thiophanate-methyl and triflumizole are commonly used for control. Foliage can be protected by spraying with copper-containing fungicides.

Nurseries reported using mefenoxam (100%) and fosetyl-Al (86%) as their main method of chemical control. Methyl bromide (14%) was used as a fumigant. Other methods used were *Trichoderma* and adding chlorine to the irrigation system.

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**Powdery Mildew**

**Pathogen:** *Erysiphe* spp., *Sphaerotheca* spp.

**Description:** The name of this fungal disease is from the white, powdery appearance on the surfaces of leaves and sometimes other plant parts. Powdery mildew is caused by a number of different fungi and many are host specific. Powdery mildew fungi are obligate parasites, able to survive only on living tissue. However, if cleistothecia (resting stages of the fungus) are formed the fungus can survive. On many species of perennial plants, the fungus survives as mycelium in dormant buds. Most powdery mildew fungi grow over the surface of the leaf, sending haustoria into the leaf epidermal cells. The fungi produce masses of spores, which become airborne and spread to other plants. The surface must be relatively dry for the haustoria to infect the leaf although spores may be dispersed but high humidity is also necessary for infection. Splashing water can spread the spores. Powdery mildews are favored by moderate temperatures (68°-86°F) and low light.

**Damage:** Leaves may yellow, then brown and die. Leaves that do not die may curl and be distorted. Leaves are covered with a grayish powder. Other infected tissues such as buds and stems may be distorted and misshapen.

**Biological control:** None

**Cultural control:** Syringing plants with water or water + surfactant in the afternoon may help keep leaves wet and reduce infections.

**Chemical control:** Chemical controls for powdery mildew can be preventative or curative. Care must be taken to avoid resistance to some of these fungicides.

*Protectants* (applied to healthy tissues before infection takes place): wettable sulfur, myclobutanil, fenarimol, triadimefon, thiophanate-methyl, propiconazole, stylet oil, triforine, and neem oil.

*Curatives* (can be applied after disease is noted): piperalin, lime sulfur, potassium bicarbonate.

Seventy-one percent of nurseries used fenarimol to protect against powdery mildew. Other materials used were myclobutanil (43%), triadimefon (43%), sulfur spray (43%), azoxystrobin (29%), copper spray (29%), mancozeb (29%), thiophanate-methyl (14%), propiconazole (14%), and Safer soap (14%). Other control measures were pruning and washing the foliage.

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**Bacterial leaf spots**

**Pathogens:** *Pseudomonas* spp., *Xanthomonas* spp.

**Description:** The bacterium survives in or on infected plant tissue. When the weather is warm and moist, bacteria ooze out of
The leaf spots and are splashed to other plants. The bacteria usually enter natural openings or wounds. Spread is more severe in wet weather.

**Damage:** Angular, black areas on leaves. Young leaves and shoots are distorted. In severe attacks, elongated lesions form on the twigs. Bacteria ooze from infected tissues in wet weather. In severe cases, the bacterium will spread to twigs and cause girdling cankers.

**Biological control:** Moderate control may be achieved with preventive applications of streptomycin sulfate

**Cultural control:** Keep water off the leaves- use drip or microsprinklers. Remove and destroy infected tissues. Disinfect pruning tools regularly.

**Chemical control:** Apply cupric hydroxide or fosetyl-Al in the spring and summer to protect the new foliage. If symptoms were severe the previous year, spray with Bordeaux mixture or a copper fungicide at bud break. There are no curative controls since the bacteria are systemic in infected plants.

Growers used a variety of copper compounds, especially copper hydroxide (86%) for control of bacterial spot. Some also reported that they prune out infected sections and increase spacing between plants.

**Fungal leaf spots**

(Adapted from Dreistadt et al. 1994)

**Pathogens:** many including *Pseudomonas sp.*, *Kabatiella sp.*, *Gloeosporium sp.*, *Diplocarpon mespili (= Entomosporium mespili)*, *Seimatosporium arbuti*, *Mycosphaerella arbuticola*, *Phyllosticta fimbriata*, *Sphaceloma sp.*, *Alternaria*, *Septoria* and *Cercospora*

**Description:** Fungal leaf spots and blights usually occur when by leave are wet for an extended time and under high humidity. Fungal leaf spots are usually tan to black and concentrated along the leaf margin and veins. Often the spots will grow together and sometimes forming concentric rings of dead, brown tissue. Sporulation is often visible within dead tissue and helps distinguish it from bacterial leaf spots. Leaf-spotting pathogens survive on fallen leaf litter and on dead branches or cankers.

**Damage:** Discolored leaves and leaf spotting. Often infected leaves drop prematurely and in severe cases the entire tree may be defoliated.

**Biological control:** None

**Cultural control:** Avoid wetting the foliage when watering. Rake and dispose of leaves. Prune off branches showing dieback and severe leaf blight.

**Chemical control:** Protective sprays of thiophanate-methyl or a copper fungicide.

Growers used a number of different materials for control of fungal leaf spots. Seventy-one percent reported that they used thiophanate-methyl as well as copper hydroxide (57%) and mancozeb (43%). As with bacterial leaf spot, growers also prune and increase spacing between plants.
Vertebrates

Vertebrate/Snail Control

Growers were asked to list any vertebrate pests that were problems. Squirrels were the most common problem. Other animals were birds, gophers, raccoons, rabbits, and rats/mice. Snail control is also important. In 1997, 7244 pounds of metaldehyde was applied in the top 5 nursery production counties (CDPR PUR, 1997).

Brown garden snail (*Helix aspersa*)

(Ohlendorf and Flint, 1999)

**Description:** Snails are mollusks and move along the ground along on a muscular appendage that secretes mucus to facilitate movement. Brown garden snails are hermaphroditic, thus they are able to fertilize their own eggs. Adult brown garden snails lay eggs into the soil. Nearly 100 eggs are laid at a time and they may lay eggs up to six times a year. Snails mature in about 2 years. Snails are most active during the night. They retreat to dark, moist areas during the day.

**Damage:** Snails feed on a variety of living plants by scraping the leaves with their rasp-like mouthparts. They can chew irregular holes in leaves and can clip off smaller, succulent plants.

**Biological control:** The most common biological control for the brown garden snail is the predaceous decollate snail (*Rumina decollata*). Although it feeds only on small snails, it is an effective method of control in areas where it can be used (Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Ventura, and Tulare counties).

**Cultural control:** Elimination of areas for snails to hide during the day is nearly impossible in a nursery. Snails can hide under containers, in the canopy of plants, or under mulch. In small areas, handpicking can remove many snails but this must be done on a consistent basis. Likewise, placing boards or other material out as shelter can trap snails. The accumulated snails can then be scraped off and destroyed. Copper foil barriers can be effective to keep snails from crawling into pots but each pot must have a band encircling it.

**Chemical control:** Snails can be controlled using baits. Metaldehyde baits are the most commonly used type. Iron phosphate is a relatively new control material with very low toxicity but cost the material is greater than that of metaldehyde so it has not yet been widely accepted.

**References**


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