

Crop Profile for Avocados in California

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General Production Information

- **California's Ranking.** California produces 95% of the avocados grown in the United States and 10% of the world's production (1,2).
- **Acreage.** Avocados were grown on 60,000 fruit-bearing acres in California in 1998 with 6,000 growers and an average farm being 10 acres (3,5,7). Avocados are continually harvested over an extended period with the trees going through two year productivity cycles.
- **Production.** In 1996/1997, California produced 329,000,000 pounds of avocados, with a market value of \$259,000,000 (2,3,5). In 1997/1998, California production was lower, 305,000,000 pounds for \$261,000,000 due to impacts of El Niño, avocado thrips, and the perseia mite (2,3).
- **Historical Production.** From 1990 to 1998, California's average production was 323 million pounds, with typical fluctuations of 5% (2,3).
- **Yield Per Acre.** The yield per acre varies between 4,000 and 7,500 lbs/acre (2,3,5). A typical tree produces 60 pounds of fruit per year. There are typically 100 trees per acre.
- **Varieties.** The Hass variety accounts for 84% of the avocado harvest and 94% of the industry's market value. The Fuerte variety accounts for 4% of the harvest, with other varieties accounting for the remaining 12% of the harvest (1).
- **Exports.** California exported 6.3 million dollars of avocados in 1997, 2% of the state's crop (1).
- **Fresh Market.** 100% of the California avocado crop is fresh market. Processed avocados are import products.
- **Cost Per Acre.** The total cost to produce an acre of avocados in California is typically \$4,700. In some of California's avocado production areas, water (irrigation) can account for up to two-thirds of input costs.
- **IPM.** California avocados use relatively few chemicals to control insect pests. Beneficial insects are used as part of an Integrated Pest Management (IPM) approach in which harsh chemicals are avoided to maintain this balance.

Production Regions

Avocados are grown primarily in southern and central California, typically in regions tempered by coastal climates. Avocados are grown on approximately 60,000 acres. Most of the avocado acreage lies between San Luis Obispo and San Diego.

Avocados are produced in 15 counties but five coastal counties account for essentially all of the state's

production. San Diego County is the leading county, producing nearly 47% of California market value for avocados (using 39% of the state's avocado producing acreage). Other counties with significant production are Ventura (24%), Riverside (14%), Santa Barbara (13%), and Orange (3%) (2). Though most of the state's acreage for avocado production lies within regions that are tempered by coastal temperature and humidity moderating effects, some of the state's production is in central locations such as the San Joaquin Valley where temperature and relative humidity are substantially different (1, 2, 3).

Executive Summary

Limited Chemical Use. Compared to many other crops, production of avocados in California is accomplished with minimal use of chemical pest control methods. With the important exception of the current threat from avocado thrips, discussed below, most insect pests (including mites and snails) are controlled through the presence of natural predators and the industry's cultural practices. For example, all chemical insecticides are applied to less than 0.5% of California's avocado acreage with the exception of chemicals that are currently used to treat avocado thrips, avermectin with narrow range oil and sabadilla alkaloids (AGRI-MEK with UNIPAR-415, and VERATRAN-D), which are applied to a significant portion of the acreage, and metaldehyde, which is applied as a bait to 3% of the state's acreage (6). Though perseia mite, greenhouse thrips, western avocado leafroller, and a few other insect pests are serious concerns to California's avocado industry, most insect threats are occasional and control methods are initiated only when careful monitoring indicates a need for action. Similarly, chemical fungicides are applied to less than 2% of California's avocado acreage (6).

Industry Uses Integrated Pest Management. The existing balance between most beneficial insects and pests in avocado groves necessitates that the industry carefully follow IPM practices. The use of excessive or harsh pest control methods adversely impacts the ongoing balance in pest management.

Avocado Thrips - A Major Economic Pest. In contrast, avocado thrips have recently become a major economic pest to California avocados. In recent years, avocado thrips have resulted in significant decreases in yield and fruit grade. It is estimated that California growers have lost 35% to 45% market value. Fruit grade reductions lower the price received for avocados by 50% or more. Pest control options have been limited and no available pest management tool is sufficiently effective against avocado thrips without adversely impacting the balance with beneficial insect populations. Major research efforts are underway to develop an effective management of this pest.

Limited Disease Problems. Root-borne fungal diseases are more critical to California's avocado industry than foliar-based diseases. Root rot and phytophthora canker (collar rot) are the two most significant root pathogens. In contrast, foliar fungal diseases are rarely of commercial significance to California avocados. Very few fungicides are registered for use on avocados. These include fosetyl-al (ALIETTE), mfenoxam (RIDOMYL GOLD), and copper hydroxide. Copper hydroxide is used as a disinfectant for equipment that has been used around an infected area. The most common fungicides are only applied to less than 2% of California's avocado acreage (6). Chemical tools are needed for the eventuality of disease outbreaks. These remaining tools should be maintained for long term disease

control.

Availability of Chemical Tools Crucial. There are a limited number of chemical pesticides approved for use on avocados. It is crucial to ensure that these few pesticide products remain available to the industry. Even though California's avocado industry uses chemical pesticides sparingly on limited acreage, these chemicals continue to be key components in the overall management of pests by the avocado industry. Retention of these products for the industry will have an inconsequential impact on the "risk cups" of these chemicals since the avocado acreage is limited and the anticipated uses would be only sporadic and confined to a small percentage of the overall acreage. These chemical registrations need to be maintained.

Cultural Practices

Seven varieties of avocados are grown commercially. The Hass variety dominates production, accounting for 84% of the avocados harvested and 94% of the market value in California due to higher consumer acceptance and demand for this variety. Other varieties include Bacon (4% of the state's acreage), Fuerte (3%), Zutano (2%), Pinkerton (2%), Reed (1%), and Gwen (1%) (3).

Avocados are evergreen trees that produce one crop per year. Due to California's unique coastal microclimate, avocados are harvested year round with a typical tree yielding 60 lbs of fruit per year (1, 7). An individual tree rotates through a 2-year growing cycle with yields being higher every other year. The official avocado crop year runs from November 1 through October 31. The size and oil levels of the harvested fruit, in part, determine the grade of the harvest.

Avocados are ideally suited to regions with well-drained, fine sandy loam soils. Micro sprinkler and drip irrigation systems typically are used to deliver water to the grove floor. Avocado roots are relatively shallow, so deep watering is unnecessary (1).

Water can account for up to two-thirds of all input costs associated with producing avocados in California. The high cost of water in some areas has led to reduced usage, stressing trees and making them more vulnerable to both insects and diseases.

Insect Pests

AVOCADO THRIPS

Damage. The avocado thrips (discovered in Ventura County in June, 1996) is the most injurious pest of California avocados, having the greatest adverse economic impact. The pest attacks young avocado

foliage and fruit causing the fruit to drop from trees, lowering the grading, or rendering the fruit unmarketable. It is estimated that growers have lost 35% to 45% market value (or up to \$50,000,000). Impacted fruit are downgraded to a lesser quality, typically reducing the price received for the "standard" size avocado (about 8 ounces) from \$1.48 to \$0.87 during the 1998-99 crop year, equivalent to a 40% decrease in price. In fact, new avocado grades have been established in 1999 to correlate pricing and distribution to damage from avocado thrips. Significantly damaged fruit (> 75% surface damage) are down-graded and priced below \$0.87. In more serious infestations, fruit are culled (unmarketable) due to damage from avocado thrips (4).

Thrips damage to mature fruit causes unsightly brown scarring which leads to downgrading of the fruit and economic loss. On fruit, feeding by avocado thrips begins near the calyx, gradually producing a scar that can cover the entire fruit. The fruit subsequently develops a leathery, brown skin. Feeding is most common on young fruit. Older fruit with thicker skin is less susceptible to attack.

Avocado thrips feed on young leaf and fruit tissue. Its feeding on young leaves causes irregular scarring lines on both sides of the leaf, typically concentrated along the midrib and lateral leaf veins. Feeding on young fruit can lead to fruit drop and feeding on fruit stems of larger fruit can lead to further fruit loss (3).

The pest is now found in all California growing regions with the exception of the San Joaquin Valley. Significant infestations are ongoing in the southern coast production regions of San Diego, Orange, Riverside, Ventura, Santa Barbara, and San Luis Obispo counties. However, due to this pest's mobility and adaptiveness, it is anticipated that avocado thrips will be everywhere in the state, eventually resulting in economic losses even in regions with cold winter temperatures (central coast and San Joaquin Valley regions).

Description of Pest. Avocado thrips, a new pest, appeared on avocados in Ventura County, California in June of 1996. Adults and larvae can be easily confused with citrus thrips and western flower thrips. Avocado thrips lay eggs in young fruit and leaf tissue, and have two larval instars and a prepupal, pupal, and adult stage. The first instar is pale white just after hatch, and takes on a deeper yellow color after it has fed. The second instar is larger and more robust. Larvae are typically found along the venal ribs on the underside of younger leaves and on young fruit (3).

Monitoring. Growers monitor the groves during bloom time to determine the amount of fruit set and the intensity of the avocado thrips infestation. If the thrips population is at a significant level, typically when there are two to five thrips per leaf, chemical treatments are indicated and typically continued until the fruit is the size of a fifty-cent piece (i.e., a 2 inch diameter) or hardened off.

CONTROLS

Cultural:

Healthy Trees. Although cultural practices encourage vigorous tree growth, fast growth can be a mixed-

blessing by encouraging infestation by avocado thrips. Vigorous growth and the accompanying healthy foliage and growing fruit can be attractive to avocado thrips and should be monitored accordingly.

Biological:

Biological control agents have not been observed to reduce avocado thrips populations below damaging levels.

Predaceous Thrips. *Franklinothrips vespiformis*, banded wing, and black hunter thrips are naturally occurring predaceous thrips that have been observed to respond to the presence of avocado thrips populations. These predator thrips are just starting to establish a response to avocado thrips but are currently inadequate for suppression of the avocado thrips populations. However, the adult *Franklinothrips* are being assessed for control of avocado thrips in 1999. This new predator is being considered for commercialization by European and United States insectaries.

General Predators. General predators such as predatory mites and green lacewings also feed on avocado thrips. However, these biological control agents have not suppressed avocado thrips populations.

Chemical:

Once a spray program is initiated, treatments to reoccurring populations are continued until the fruit has reached the size that it will no longer host the pest (typically when the fruit diameter is larger than 2 inches). It is important to use more than one chemical treatment regime so that resistance can be minimized. The following two chemicals are the preferred treatments for avocado thrips.

- **Avermectin.** 14 day PHI. Avermectin (a.k.a. abamectin, AGRI-MEK) is applied at a rate of 0.012 to 0.024 lb ai per acre up to 2 times per year. Current use for control of avocado thrips is allowed under an Emergency Exemption (Section 18 registration). This pesticide was not used on Avocado acreage prior to February, 1999. It is ideal for treatment of the pest due to the chemical's limited impact on beneficial insects. Avermectin is considered a very "soft" chemical due to the ingredient's relatively low impact on the balance between the pest and beneficial organisms, particularly when compared to the impact of conventional chemicals. It is anticipated that avermectin will be used on much of the state's avocado acreage in 1999. It is a key component in the industry's battle against avocado thrips. The disadvantages of avermectin are that it is very expensive and must be used with a potentially phytotoxic narrow-range oil (UNIPAR-415). Use is prohibited when bees are active in the groves. The reentry period is 12 hours.
- **Sabadilla Alkaloids.** 0 day PHI. (VERATRAN-D) Sabadilla alkaloids are applied at a rate of 10-15 lbs/acre. Reapplications are typically made every 1 to 2 weeks as thrips populations reappear. This product is applied with sugar (e.g., sucrose or molasses) to attract thrips. The effectiveness of sabadilla alkaloids is sometimes variable, especially in cool wet weather, but it is one of the few alternatives available for control of avocado thrips. Sabadilla is less likely to impact beneficial insects than conventional chemical treatments. Sabadilla alkaloids are useful alternates

to avermectin during periods when bees are active in the groves, since avermectin applications are prohibited during these periods. The product can be used by certified organic growers. The restricted entry interval is 24 hours.

The following chemicals, though registered, are not typically used to control avocado thrips:

- **Malathion.** 7 day PHI. It is applied at a rate of about 0.5 lb ai/acre and was used in 1996 to treat less than 1% of avocado acreage. Treatment with malathion is usually not recommended because it kills natural predators and often leads to outbreaks of other pests such as brown mites. It has a restricted entry interval of 12 hours.
- **Methomyl.** 3 day PHI. Methomyl (LANNATE) is an oxime carbamate that provides variable effectiveness and a cheaper alternative to other pest management tools for control of avocado thrips. Treatment with methomyl is usually not recommended because it will kill natural predators and often results in outbreaks of other pests. Methomyl can be disruptive to IPM programs. It is applied to less than 1% of the avocado acreage at a rate of about 0.75 lb ai per acre, and can be applied multiple times per season. It is applied to less than one percent of avocado acreage. Methomyl has a restricted entry interval of 48 hours.
- **Narrow Range Oil.** 0 day PHI. Narrow range oil (UNIPAR 415) can be applied by itself or in a tank mix with avermectin (AGRI-MEK) as part of the Section 18 registration described above. Oils require good coverage to be effective. They can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects and can be phytotoxic, particularly when applications are made at high temperatures. Early season use can cause flare-ups. It is an inexpensive treatment but provides somewhat variable results. Prior to the use of narrow range oils in the avermectin Section 18 tank mix, only about 4% of the avocado acreage were treated with oils, primarily for the control of perseae mite. Narrow range oils can be used by organic growers. The restricted entry interval is 4 hours.
- **Azadirachtin.** 0 day PHI. Azadirachtin (NEEM OIL) is applied at label rates and has demonstrated variable effectiveness. This product is relatively expensive, particularly when compared to its efficacy on avocado thrips. The restricted entry interval is 4 hours.
- **Pyrethrin plus Rotenone.** 0 day PHI. A combination product containing pyrethrin and rotenone is applied at label rates for control of avocado thrips. It has been shown to be variable in effectiveness. Pyrethrin products are not effective over long periods. The restricted entry interval is 12 hours.
- **Pyrethrins and Piperonyl Butoxide.** 0 day PHI. (PYRENONE) A combination product containing pyrethrins and piperonyl butoxide is applied at label rates to avocado groves to control avocado thrips. The effectiveness of this product on this pest has been variable. It is not effective as a long term solution to avocado thrips. The restricted entry interval is 12 hours.

PERSEAE MITE

Olygonichus perseae

Damage.Persea mite is a recently introduced pest of avocados. It occurs in most avocado-growing areas of California except the Central Valley and is most damaging to the Hass variety of avocado, but also attacks Gwen and Reed varieties. The early season damage caused by persea mite mainly affects the underside of the leaf and produce webbing along the midrib and veins. As persea mite populations increase, feeding causes leaf drop. A heavily infested tree will have a litter of yellow-spotted, green leaves on the ground.

Description of Pest. Colonies of persea mite occur on undersides of avocado leaves, beneath canopies of delicate webbing where feeding and reproduction takes place. The webbing protects the mite from many common predators. Populations begin building in March and generally reach their peak in July and August. Populations diminish rapidly in summer when hot conditions arise or in winter when temperatures are cool.

Monitoring.Monitoring for persea mite begins in mid-March. When necessary, predatory mite releases begin, in small amounts on a monthly basis, in late March or early April. In the early stages of infestation, it may be necessary to treat with oil by helicopter in late July or August though this may not be possible due to the phytotoxicity of oils at warm temperatures.

CONTROLS

Cultural:

Washing Leaves on Small Trees. Growers remove mites and destroy nests by washing the leaves on small trees with water under high pressure. The pressure from a garden hose is typically not sufficient. This technique is not feasible under most growing conditions due to the cost and impacts of the water and the mechanics of obtaining high-pressure lines in the groves.

Plant Health.To maintain the flush of new growth that occurs after mite-induced leaf drop, growers adequately irrigate and fertilize the tree. In severe cases white washing is sometimes required to protect the tree trunk from sunburn after leaf drop has occurred.

Dust Reduction. Occasionally, a water truck is used to prevent dust on dirt roads, especially when during heavy use.

Biological:

Galendromus Mites. Commercially available species of *Galendromus* have proved to be helpful in controlling pest populations in some groves. Release of 2,000/acre followed by 5,000/acre beginning in the spring. This rate of release is not high enough to bring about control in one season, but does introduce the predator into the grove for eventual on-going biological control of persea mite. Releases are best made when leaves are moist. If leaves are dry, the mites can be applied in a solution with water from a backpack mister or by moistening foliage with a spray bottle and shaking the mites onto the moist leaves.

***Neosileus californicus*.** *Neosileus californicus* is a specialized spider mite predator that has been used in biological control for several crops including avocado. When warm weather comes, *Neosileus californicus* is introduced and the predator goes into the canopies to search for perseia mite and other prey.

Other Predators. There are numerous predators that feed on perseia mite: predaceous thrips, including sixspotted thrips (*Scolothrips sexmaculatus*), black hunter thrips (*Leptothrips mali*), and *Franklinothrips vespiformis*; native predaceous mites (*Euseius hibisci* and *Galendromus annectens*); and the spider mite destroyer (*Stethorus picipes*). Because of the protective webbing produced by perseia mite, many predators cannot feed on the eggs, nymphs, and adults in nests. When moving between colonies, however, perseia mite are vulnerable to predation. The preserving of hibisci populations is important. *Euseius hibisci*, which can maintain and increase populations on pollen in the absence of live prey, is the major controlling factor.

Chemical:

Chemical controls of other pests such as the avocado thrips impact the populations of perseia mite, which is sensitive to these non-specific applications. If perseia mite are present at potentially significant levels, then the pest management program should be designed to include perseia mite control as a secondary goal.

- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. They are the most common chemical treatment for perseia mite and are applied to 5% of the avocado acreage. It can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects. It is an inexpensive and effective treatment. The restricted entry interval is 4 hours.
- **Azadirachtin.** 0 day PHI. Azadirachtin (NEEM OIL) can be applied at label rates and has demonstrated variable effectiveness. The product also has a relatively high cost. Since this is a relatively new active ingredient, there are no summary data on the level of its use. The restricted entry interval is 4 hours.

GREENHOUSE THRIPS

Heliathrips haemorrhoidalis

Damage. Economic damage from greenhouse thrips is from scars or blemishes larger than 3/4 inch diameter that cause fruit to be culled. Greenhouse thrips are a more significant pest in the coastal regions due to the moderation in temperature. The preferred habitat of this pest is in the large clusters of fruit where temperatures and humidity extremes are moderated, so trees with limited clusters of fruit are less susceptible to greenhouse thrips. Thrips injury on foliage begins to show in June as small, white-gray patches on upper leaf surfaces where thrips are found in the greatest numbers. Feeding probably causes little damage to tree health. Mexican seedling avocados and the Hass variety are extremely susceptible.

Description of Pest.Greenhouse thrips are commonly found on the inside of the tree or the north side, away from direct sun exposure. The greenhouse thrips occurs on avocados, citrus, and a large number of ornamental plants in California. Almost the entire overwintering greenhouse thrips population is destroyed annually by natural leaf drop during flowering and these thrips do not reappear in numbers sufficient to cause injury until early summer. On varieties such as Hass, where the majority of the thrips population resides on the fruit, most of the population is removed annually at harvest. About five to six generations of greenhouse thrips occur annually.

Monitoring.Fruit is carefully inspected where it contacts other fruit or foliage for signs of initial feeding injury or the presence of greenhouse thrips in clusters. If thrips populations are present, they are easy to find by early to mid-May and minimal economic damage will have occurred. Without the intervention of extreme weather conditions, successful biological control, or insecticide applications, populations of greenhouse thrips increase and cause damage (3).

CONTROLS

Cultural:

Strip Picking.On the Hass variety, where thrips are located primarily on the fruit, an important cultural practice that can significantly reduce greenhouse thrips damage is strip picking of fruit in an early harvest (June/July). When fruit prices are low and early harvest is less economically feasible, growers select pick fruit to reduce fruit clusters to reduce the thrips population. This denies thrips an important harborage during summer months, especially on the Hass variety where the fruit is the primary feeding and breeding substrate. Strip picking is also helpful to the second years crop in an infected grove.

Early Harvest.The earlier the harvest, the less accumulated damage occurs. Early harvest also minimizes the crop-to-crop overlap period necessary for thrips movement to the new crop and can therefore significantly reduce the damage that will occur on the next season's crop.

Record Keeping. Growers sometimes keep a record of the locations of the previous years' infestations and check these areas in late March or during April to determine the potential for damage in the current year. Greenhouse thrips populations tend to occur within the most moderate microclimate areas of a grove, which are consistent from one year to the next.

Biological:

Thripobius semiluteus. This parasite is generally expensive to release and, currently, is not available commercially (though it may become available in the future). The parasite is typically released in April and May when thrips are easily located by the parasite. Once established in a given area of a grove, it can be moved into other areas on foliage bouquets or on clipped fruit containing parasitized thrips larvae. *Thripobius semiluteus*, which attacks second instar larvae, has been released successfully in some groves along the coast although it does not provide consistent control.

Green Lacewings.General predators such as green lacewings also feed on greenhouse thrips. However,

these biological control agents have at most only suppressed greenhouse thrips populations. They are introduced at 30,000 to 40,000 per acre and at reduced numbers at later times.

***Megaphragma mymaripenne*.** An important natural enemy of greenhouse thrips is a parasitic wasp, *Megaphragma mymaripenne*, that attacks eggs. Three species of predaceous thrips (*Franklinothrips vespiformis*, *Watsoniella flavipes*, and black hunter thrips, *Leptothrips mali*) are also known to prey on greenhouse thrips.

Chemical:

Thrips populations may be treated in spring with pyrethrin. Use of a pyrethrin is recommended to avoid mortality of natural enemies that control greenhouse thrips and other pests. Malathion sprays invariably lead to outbreaks of other pests such as mites and omnivorous looper. Chemical treatments are concentrated on trees that are infested (3).

- **Malathion.** 7 day PHI. Only infested trees are treated to avoid destroying natural enemies of mites, loopers, scales, and other potential secondary pests. Spot treatments are often the first approach used. Application rates are 0.5 lb ai/acre. Malathion is used on less than 0.5% of the avocado acreage. The restricted entry interval is 12 hours.
- **Pyrethrin.** 0 day PHI. Pyrethrin is applied at rates of less than 0.5 lb ai/acre. Repeat applications are usually needed at 2 to 3 week intervals because there is little residual activity. Control may only be partial. It is applied to about 0.5% of the avocado acreage. The restricted entry interval is 12 hours.
- **Sabadilla Alkaloids.** 0 day PHI. Sabadilla (VERATRAN-D) is applied at a rate of less than 0.1 lb ai/acre. Reapplications are typically made every 2 to 3 weeks as thrips populations reappear. Sabadilla is less effective than pyrethrin and expensive to use. The effectiveness of sabadilla is sometimes variable, especially in cool wet weather, but it is the best product currently available. Sabadilla is less likely to impact beneficial insects than the other chemical treatments. There is no use data available on this relatively new active ingredient. The restricted entry interval is 12 hours.
- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. It can effect bloom and should not be applied to young fruit. The oils often have to be used with spot treatment of malathion in order to become sufficiently effective. The oil does kill some beneficial insects. It is an inexpensive but with variable results. Oils are applied onto less than 5% of the avocado acreage. The restricted entry interval is 4 hours.
- **Methomyl.** 1 day PHI. Methomyl (LANNATE) provides variable effectiveness when used at label rates. Treatment with methomyl is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Methomyl is an oxime carbamate. It is applied at a rate of about 0.75 lb ai/acre onto less than 0.5% of the avocado acreage. Methomyl has a restricted entry interval of 48 hours.

AMORBIA (Western Avocado Leafroller)

Amorbia cuneana

Damage. Populations of amorbia exist in most avocado groves in California. The worst infestations are typically found in the coastal growing regions. Mature avocado trees can tolerate considerable leaf damage by amorbia larvae without severe effects on tree growth or fruit yield whereas young groves can be more susceptible. Occasionally, the populations of amorbia increase to significant levels and cause severe fruit damage. Fruit damage from amorbia occurs where larvae web leaves against fruit, or where webs are made between touching fruit. In these protected sites larvae feed on fruit skin and cause scarring, which, if severe enough, causes downgrading or culling (3).

Description of Pest. Adult female moths lay light green, oval-shaped eggs. Eggs are generally laid on upper leaf surfaces. Amorbia larvae roll and tie leaves together with silken web in which the larva feeds on leaves and fruit. Sometimes, larvae spin silk between fruits that touch each other. As the larvae develop, they go through five stages (instars).

Monitoring. Growers monitor for amorbia larvae in groves with pheromone traps and visual inspection in late spring. They look for webbing and leaf rolls in young foliage and feeding damage on young and mature fruit located on the outside of the canopy. Decisions related to biological or chemical control are based on pest pressure, the presence of beneficial parasites and anticipated damages. If the level of beneficial parasites is increasing in the grove, the amorbia population will decrease and no chemical treatment is needed.

CONTROLS

Cultural:

There are no cultural control methods used to specifically target amorbia infestations, however several techniques are helpful in suppression of populations.

Pruning. Pruning is performed to allow more light and air flow into the tree, producing a less desirable environment.

Cluster Thinning. Fruit cluster thinning during picking can eliminate sites for nesting.

Biological:

Trichogramma platneri. *Trichogramma platneri*, a tiny wasp, is one of the most effective parasites of amorbia eggs. Amorbia egg masses that appear black have probably been parasitized by this beneficial wasp. These beneficial parasites are commercially available and are routinely introduced to control amorbia populations. Parasite egg cards are attached to at least 4 trees per acre for a total minimum release of 100,000 parasites/acre/season. These parasite eggs are sometimes eaten by ants. These beneficial parasites provide good biocontrol of amorbia. Populations are monitored by trapping systems.

Tachinid Fly. A tachinid fly, which is similar in appearance to the common housefly attack the larvae.

Small brown pupal cases of tachinid flies are often found near the larger parasitized amorbias pupal cases. This pest is not artificially introduced.

Other Beneficial Parasites. Beneficial parasites play a major role in keeping amorbias populations below economically damaging levels in most California avocado groves. A naturally occurring nuclear polyhedrosis virus can also control larvae but causes epidemics only when larval populations are high.

Chemical:

Several registered pesticides are available to control amorbias but their impact on beneficial insects limits their usefulness. Chemical treatments specific to control amorbias are rare, typically triggered only every 5 to 10 years. The status and commodity on a neighboring grove can often make a difference.

- ***Bacillus thuringiensis*.** 0 day PHI. *Bacillus thuringiensis* (DIPEL) provides variable control of early instars of the worm. It is not effective on adult amorbias or mature larvae. The Restricted entry interval is 4 hours.
- **Methomyl.** 3 day PHI. Methomyl (LANNATE) is an oxime carbamate that provides variable effectiveness when used at label rates. Treatment with methomyl is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Methomyl can be disruptive to IPM programs. It is applied at a rate of 0.75 lb ai per acre and been applied to less than 0.5% of avocado acreage. Methomyl has a restricted entry interval of 48 hours.
- **Malathion.** 7 day PHI. Malathion is an organophosphate. It has been applied at label rates to less than 0.5% of California's avocado acreage. Treatment with malathion is not recommended because it will kill natural predators and may lead to outbreaks of other pests. It is applied at a rate of 0.5 lb ai/acre. It has a restricted entry interval of 12 hours.
- **Permethrin.** 7 day PHI. Permethrin (AMBUSH, POUNCE) is a pyrethroid that provides variable control of amorbias. It is applied at a rate of less than 0.5 lb ai/acre, and has been applied to about 0.2% of avocado acreage. It is not typically effective enough on amorbias to justify commercial use. It has a restricted entry interval of 12 hours.
- **Carbaryl.** 5 day PHI. Carbaryl (SEVIN) is a carbamate. It is a broad-range insecticide that can be used to treat several insect pests. It is rarely used by the avocado industry because it is a harsh chemical that can have disruptive effects on the balance with beneficial predators. It should not be applied during bloom as it is toxic to bees. There were no reported uses of carbaryl on avocados in 1996. Carbaryl may be applied in combination with narrow range oil at reduced rates which increases the survival of natural enemies and reduces the risk of phytotoxicity. The restricted entry interval for carbaryl is 12 hours.

OMNIVOROUS LOOPER

Sabulodes aegrotata

Damage. Omnivorous loopers are common in many avocado groves in low numbers, unless there has been an upset caused by broad-spectrum chemicals for the control of other pests, such as greenhouse or

avocado thrips. Fruit damage can be caused by young or old larvae. When young fruit is fed on, its shape becomes distorted. When larger fruit are fed on, the fruit surface is scarred, which may cause it to be downgraded. Mature avocado trees can tolerate considerable leaf damage without severe effects on growth or yield.

Description of Pest. The omnivorous looper is also called an inchworm or measuring worm. The name "looper" comes from the crawling or looping movement of the larva as it extends its forelegs outward and then draws up the rear legs, creating a loop. Because moths are strongly attracted to security lights or other bright light sources in or near the grove, larval infestations are often concentrated near trees adjacent to light sources. Depending upon temperatures and humidity, the entire life cycle takes 9 to 11 weeks. There are five generations per year in the warmer southern parts of California.

Monitoring. Growers monitor larvae throughout the spring and summer, particularly from May through July, at 7- to 10-day intervals. Pheromone traps are used primarily to identify periods of peak flight activity. Shortly after peak flights, growers look for larvae in leaf rolls and in areas where fruit touch each other, mainly on the south and east quadrants of tree. Growers also check for evidence of parasitism. When levels of larvae are high, growers watch for evidence of a viral disease within the population, which will cause significant decreases in the pest population within 2 weeks.

CONTROL

Cultural:

Pruning. Growers prune individual trees to open the canopy to light or remove every other tree in a thinning pattern to reduce the severity of an avocado worm infestation. An ideal environment for these worms is densely canopied trees in groves where large trees form a continuous canopy of foliage.

Biological:

***Trichogramma platneri* Parasites.** 0 day PHI. Releases are made at the peak of egg laying and then again 2 weeks later. Parasite egg cards are placed on 4 trees or more per acre for a total minimum release of 100,000 parasites/acre/season. The pupal stage of the looper is often parasitized by a tachinid fly about the size of the common housefly.

Other Parasites. Several tiny wasps parasitize eggs and larvae of this looper. One wasp, *Trichogramma platneri*, is commercially available for purchase and release. Granulosis virus frequently infect and kill looper larvae when populations become large. An epidemic results and the population rapidly declines within 1 to 2 weeks. Spiders also feed on loopers and are more abundant in groves that have not been sprayed with a pesticide or subject to a freeze.

Chemical:

- ***Bacillus Thuringiensis.*** 0 day PHI. *Bacillus thuringiensis* (DIPPEL) provides effective control when used to control early instars of the worm. It is also the least disruptive to the beneficial

insects. The Restricted entry interval is 4 hours.

- **Methomyl.** 1 day PHI. Methomyl (LANNATE) provides variable effectiveness when used at label rates. Treatment with methomyl is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Methomyl is an oxime carbamate. It is applied at a rate of 0.75 lb ai per acre onto less than 0.5% of the avocado acreage. Methomyl has a restricted entry interval of 48 hours.
- **Malathion.** 7 day PHI. Treatment with malathion is not recommended because it will kill natural predators and may lead to outbreaks of other pests. It is applied at an average rate of 0.5 lb ai/acre onto less than 0.5% of the avocado acreage. It has a restricted entry interval of 112 hours.

AVOCADO BROWN MITE

Oligonychus punicae

Damage. Avocado brown mite is a commonly found mite on avocados and has a large potential to cause economic damage. Damage from avocado brown mite is most pronounced in late summer and fall. Mite feeding removes chlorophyll from leaves, which reduces photosynthesis. Avocado brown mite feeds primarily on upper leaf surfaces. With severe infestations there may be some defoliation. Severe infestations tend to occur on trees in border rows, probably because the accumulation of road dust on these trees is detrimental to natural enemies of the avocado brown mite (3). When infestation occur, damage is always limited to the boarder rows with treatments not needed in the inside portions of the groves.

Description of Pest. Avocado brown mite occurs throughout coastal avocado-growing areas. It is dark brown, oval shaped, and small. Eggs are first laid along the midrib, but as populations increase, they are found distributed quite generally over the upper leaf surface. In summer there may be two complete generations per month. Brown mite and their eggs die when temperatures exceed 90 to 95F or when with the first cold weather in fall or early winter.

Monitoring. Monitoring is visual. Particular attention is given to border rows and defoliation in these trees.

CONTROLS

Cultural:

Dust Control. Growers control dust, which improves predator activity within the grove. Roads are oiled or paved. On occasion, water trucks are used to prevent dust, especially in summer months when the heat convection currents carry dust into the tree canopies (3,4).

Biological:

Generally the avocado brown mite is kept under control by natural enemies and hot or cold weather.

Spider Mite Destroyer. The spider mite destroyer (*Stethorus picipes*) has been shown to be very effective against avocado brown mite through introduction but this predator is not commercially available (4).

Other Naturally-Occurring Predators. Naturally occurring populations of the spider mite destroyer (*Stethorus picipes*), green lacewings (*Chrysoperla* spp.), dusty-wings (family Coniopterygidae) and predaceous mites (*Galendromus helveolus* and *Euseius hibisci*) are reasonably effective in controlling brown mite (3).

Chemical:

Chemical control measures have not been required in California in recent years. Major outbreaks have occurred after spraying malathion to control greenhouse thrips and omnivorous looper. If treatment for the avocado brown mite is required, treatment of individual trees in late summer or fall is the best approach to avoid an avocado brown mite outbreak.

- **Wettable Sulfur.** 0 day PHI. Wettable sulfur is applied at label rates to individual trees with high avocado brown mite outbreaks. This product is often the standard used in the southern growing regions though it is applied to less than 0.5% of the state's acreage. To avoid leaf damage, wettable sulfur treatments are not made when temperatures exceed 90°F. Wettable sulfur is ineffective in cooler coastal regions since the material must fumigate to be effective. The reentry period is 24 hours.
- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. The oil does kill some beneficial insects, particularly early in the season when pest outbreaks can result. It is an inexpensive and effective treatment. Oils are applied onto about 5% of the state's avocado acreage. The restricted entry interval is 4 hours.
- **Azadirachtin.** 0 day PHI. Azadirachtin (NEEM OIL) is applied at label rates and has demonstrated variable effectiveness and is expensive to use. There are no use data available on this relatively new active ingredient at this time. The restricted entry interval is 4 hours.

WHITEFLIES

Redbanded Whitefly: *Tetraleurodes perseae*

Nesting Whitefly: *Paraleyrodes minei*

Mulberry Whitefly: *Tetraleurodes mori*

Greenhouse Whitefly: *Trialeurodes vaporariorum*

Giant Whitefly: *Aleurodicus dugesii*

Damage. Whiteflies feed on plant sap. Honeydew excreted by nymphs collect dust and support growth of sooty mold fungus and can attract ants, which interfere with the biological control of whiteflies and other pests. Giant whitefly is of particular concern due to the large quantity of honeydew produced by this whitefly.

Description of Pest. Whiteflies are small flying insects that derive their name from the white wax covering their wings and body. While different whitefly species appear similar as adults, their immature stages are distinct.

Monitoring. Though whitefly populations are monitored as part of normal inspections, observations of their presence rarely triggers the need for specific control regimes.

CONTROLS

Cultural:

Dust Reduction. On occasion, water trucks are used to prevent dust from dirt roads, reducing the environment favorable to whitefly.

Prevention. Growers avoid moving uncertified plant materials from one grove to another and do not transport plant materials into California from out of the state. Bins are cleaned when transporting bins from giant whitefly infested areas to clean groves.

Biological:

Natural Predators. Several natural enemies attack the immature stages of whiteflies and provide partial to complete biological control when undisturbed by ants, dust, or insecticide treatment. Especially important natural enemies include parasites such as *Encarsia* spp, *Cales* spp, and *Eretmocerus* spp and predators such as *Delphastus* spp, *Chrysoperla* spp, *Geocoris* spp, and *Orius* spp. Jumping spiders feed on adult whiteflies.

Chemical:

Chemical treatment of whiteflies is not very effective and is rarely recommended. Temporary suppression may be achieved only to be followed by a resurgence of the pest. This is especially true if broad-spectrum insecticides, such as methomyl or malathion, are used. Conserve natural enemies by applying *Bacillus thuringiensis* (Bt) products for amorbias and loopers, and pyrenone or sabadilla for thrips if monitoring indicates a need to control these pests. The new active ingredient, imidacloprin, may eventually be a useful tool against whiteflies.

- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. It can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects. It is an inexpensive tool and provides variable effectiveness. Oils are applied to about 5% of the state's acreage. The restricted entry interval is 4 hours.
- **Azadirachtin.** 0 day PHI. Azadirachtin (NEEM OIL) is applied at label rates and has demonstrated variable effectiveness and is expensive to use. There are no use data compiled for this relatively new active ingredient. The restricted reentry interval is 4 hours.

GLASSY-WINGED SHARPSHOOTER

Homalodisca coagulata

Damage. The glassy-winged sharpshooter is a relatively new pest to California, and the concern is that this species may be a vector of certain plant diseases. In 1994, the sharpshooter was found in avocado orchards only in Ventura County. It causes significant damage in several commodities. Though avocados are not economically affected to date, the glassy-winged sharpshooter is a relatively new pest that has increased substantially in recent years. Furthermore, no chemical controls are available to the avocado industry.

Monitoring. In addition to visual observations, traps can be placed in areas adjacent to vineyards that serve as habitat for this insect. A treatment is warranted if after several successive warm days there is an increase in the number of sharpshooters trapped, or if more than an average of seven sharpshooters are trapped per trap per week, or if visual inspections reveal more than one sharpshooter per vine.

CONTROLS

Cultural:

Neighboring Crops/Wildlands. The greatest level of infestation is usually downwind from pastures, weedy hay fields, or other grassy areas. Riparian areas bordering groves can also be an important source of the vectors. Revegetation of riparian zones is also possible but requires extensive community involvement and government approvals.

Weed Control. Weedy grasses are eliminated whenever possible. Active monitoring is important in the control of sharpshooters.

Traps. Sticky traps are placed in areas adjacent to groves that serve as habitat for this insect.

Biological:

No biological control has been identified for specific control of sharpshooters.

Chemical:

No chemicals are specifically available to avocados to control the glassy-winged sharpshooter. The following products can be used on other commodities and may be targets for future Section 18 (emergency) registrations.

- **Imidacloprid.** 0 days PHI. Though not available to avocados, imidacloprid (ADMIRE) is effective on sharpshooters and may be appropriate for a future Section 18 (emergency) registration. Current field research is being performed in Citrus groves.
- **Dimethoate.** 28 day PHI. Though not available to avocados, dimethoate (CYGON) may be efficacious against glassy winged sharpshooter. However, this chemical is very harsh and likely would disrupt the balance with beneficial species significantly.

SECONDARY "INSECT" PESTS

ARMORED SCALES

Latania scale: *Hemiberlesia lataniae*

Greedy scale: *Hemiberlesia rapax*

Dictyospermum scale: *Chrysomphalus dictyospermi*

California red scale: *Aonidiella aurantii*

Damage. Though economically significant damage from armored scales is rare, damage from these scales can be worse on young trees where small twigs may be killed. The presence of the scales on the peel will result in fruit being culled, although fruit quality is not impaired. Greedy scale feeds on twigs and branches. Armored scales are most abundant on branches or twigs and may appear on leaves and fruit as infestations progress.

Description of Pest. Armored scales are found throughout the avocado-growing areas of California. Latania scale is the most commonly found armored scale on avocado. The occurrence of California red scale on avocado is not very common while the other two species occur commonly but at low levels that do not cause economic damage. Crawlers search for a suitable place to settle and can be spread about by dropping onto uninfested branches by wind, birds, or picking crews. Crawlers tend to settle in small depressions on twigs, fruits, or leaves and start feeding. The number of generations per year is from two to four, depending on the growing region.

Monitoring. Although chemical treatment is rarely needed, growers use double-sided sticky tape around twigs to monitor when crawlers are hatching. If the crawler population is sufficiently large, a chemical treatment may be applied at the crawler stage.

CONTROLS

Cultural:

Dust Control. Growers control dust, which improves predator activity within the grove. On rare occasions, water trucks are used to prevent dust, especially in summer months when the heat convection currents carry dust into the tree canopies (3,4).

Brushed Fruit. Though rarely performed, fruit can be machine brushed to remove scales in extreme cases.

Biological:

Natural biological control is usually sufficient for armored scale control in avocados. Both parasites and predators typically keep scales under control. As a result, chemical and specific cultural controls are very rarely practiced for armored scales.

Lady Beetles. The lady beetles *Lindorus lophanthae* (*Rhyzobius lophanthae*), *Chilocorus orbis* (*Chilocorus stigma*), and *Cycloneda rubripennis* feed on scales.

Lacewings. The California green lacewing *Chrysoperla californica*, another general predator, along with the brown lacewing, *Hemerobius pacificus*, may be found occasionally feeding on all stages of scale.

Thrips and Mites. Several predaceous thrips, including *Watsoniella flavipes* and sixspotted thrips (*Scolothrips sexmaculatus*) feed on armored scales. Predaceous mites, *Cheletomimus berlesei* and *Hemisarcoptes malus*, have also been seen feeding on scales.

Parasites. Numerous parasites, some native and some introduced, also prey on scales and include species in the genera *Aspidiotiphagus*, *Comperiella*, and *Aphytis*.

Chemical:

- **Narrow Range Oil.** 0 day PHI. In the infrequent case that control is justified for armored scale, oil is the most economical and selective pesticide available. Narrow range oils are applied at labeled rates and require good coverage to be effective, although it is best for young fruit if they are not completely treated. The oil does kill some beneficial wasps and suppresses beneficial mite populations, particularly early in the season, however the residue does not persist and parasitic wasps can emerge from parasitized scale or be commercially released soon after treatment. Treatments are timed to coincide with the end of maximum crawler emergence. This varies some with species and occurs at least twice each year. Oils are applied onto about 5% of the state's avocado acreage. The restricted entry interval is 4 hours.

SOFT SCALES

Brown soft scale: *Coccus hesperidum*

Black scale: *Saissetia oleae*

European fruit lecanium: *Lecanium corni*

Hemispherical scale: *Saissetia hemisphaerica*

Description of Pests. Economically significant damage to California avocados by soft scale is rare. Soft scales extract sap from the foliage and excrete large quantities of honeydew, supporting sooty-mold fungus. Crawlers typically appear from under the mother scale in spring before settling on leaves. Rarely do they appear on fruit.

Monitoring. Visual observations are used to determine whether triggers for treatment have been reached.

CONTROLS

Cultural:

There are no cultural practices specific to the control of soft scales.

Ant Control. The suppression of ant populations can help mitigate infestations by soft scale.

Biological:

Parasites and Predators. Usually soft scales are controlled by parasites and predators, and as a result, are rarely seen in avocado groves. If one of these scales is present, Argentine ant will usually be observed in the vicinity. Good ant control will increase parasitism of the scales.

Chemical:

Treatment is rarely needed for scale control.

- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. It can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects. It is inexpensive but provides variable effectiveness. Oils are applied onto about 5% of the state's avocado acreage. The restricted entry interval is 4 hours but can be 12 hours for some 415 oils.
- **Permethrin.** 7 day PHI. Permethrin (AMBUSH, POUNCE) is a pyrethroid applied at label rates to approximately 0.17% of the treated avocado acreage. It provides variable control of scale. It has a restricted entry interval of 12 hours.
- **Methomyl.** 1 day PHI. Methomyl (LANNATE) is an oxime carbamate that provides variable effectiveness when used at label rates. It is applied at an average rate of 0.75 lb ai per acre to about 0.2% of avocado acreage. Treatment with methomyl is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Methomyl has a restricted reentry interval of 48 hours.
- **Malathion.** 7 day PHI. Malathion is an organophosphate that is applied at about 0.5 lb ai per acre to less than 0.5% of treated avocado groves. Treatment with malathion is not recommended because it will kill natural predators and may lead to outbreaks of other pests. It has a restricted entry interval of 1 day.

SIXSPOTTED MITE

Eotetranychus sexmaculatus

Damage. Avocado trees growing in foggy areas near Morro Bay and Santa Barbara or other coastal weather influences are more likely to experience problems with this mite. Sixspotted mites are rarely a problem in San Diego and Riverside counties because of a relatively dry climate. Infested areas become brownish to purplish in color and severe infestations cause defoliation.

Description of Pest. Sixspotted mite may become a pest in avocado groves when chemical sprays used to control other pests disrupt biological control of this mite. Populations tend to be heaviest in spring and early summer. On avocado leaves sixspotted mites attack only the lower surface of the leaf, concentrating their activity along the midrib and larger veins. These mites produce webbing but not as much as perseas mite.

Monitoring. In coastal areas protected from drying Santa Ana winds, growers monitor for the sixspotted mite by sampling interior canopy leaves and inspecting the underside of the leaf with a hand lens for mite activity along the midrib and lateral veins.

CONTROL

Cultural:

Dust Reduction. On rare occasions, water trucks are used to prevent dust. Areas subject to drying east winds are less prone to attack from this mite, as it prefers higher humidity.

Biological:

Predator mites. These mites are generally kept under control by predaceous mites (*Galendromus helveolus*, when it is released for control of perseas mite, and *Euseius hibisci*) and sixspotted thrips (*Scolothrips sexmaculatus*). *Euseius hibisci*, which can maintain and increase populations on pollen in the absence of live prey, is the major controlling factor. These predaceous mites are typically released to control perseas mite and impact sixspotted mite populations as a secondary effect.

Chemical:

Spot treatments of sulfur or narrow range oil are occasionally required in warmer, humid growing areas. Temperature can be a problem due to the phytotoxicity of these products.

- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. It can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects, particularly early in the season. It is an inexpensive and effective treatment. Oils are applied onto about 5% of the avocado acreage. The restricted entry interval is 4 hours.
- **Wettable Sulfur.** 0 day PHI. Wettable sulfur can be applied at label rates to individual trees with high sixspotted outbreaks. To avoid leaf damage, wettable sulfur treatments are not made when temperatures exceed 90°F. Also, wettable sulfur typically is ineffective in cooler coastal regions since the material must fumigate to be effective. Sulfur is applied to less than 0.5% of the avocado acreage. The reentry period is 24 hours.

MEALYBUGS

Citrus mealybug: *Planococcus citri*

Citrophilus mealybug: *Pseudococcus calceolariae*

Longtailed mealybug: *Pseudococcus longispinus*

Comstock mealybug: *Pseudococcus comstocki*

Damage. Mealybugs are a sporadic pest to avocados. These pests extract plant sap, reducing tree vigor, and excrete honeydew. If a cluster of mealybugs feed along a fruit stem, fruit drop can occur. Damage is most severe in spring and fall. Though significant damage has been rare, this pest is becoming increasingly prevalent in avocado groves.

Description of Pests. Mealybugs are soft, oval, flat, and distinctly segmented. The species differ mainly in the thickness and length of the waxy filaments. Female mealybugs lay several hundred eggs on the leaves, fruit, or twigs. Newly hatched nymphs are light yellow and free of wax, but soon start to excrete a waxy cover. There are two to three overlapping generations a year.

CONTROL

Cultural:

There are no specific cultural practices.

Biological:

General Predators. Parasites provide good control of the citrophilus, longtailed, and Comstock mealybugs if they are not destroyed by treatments for other pests. Native predators include lady beetles, lacewings, and syrphid flies.

Cryptolaemus montrouzieri. The mealybug destroyer, *Cryptolaemus montrouzieri*, is a voracious feeder of the pest in both the larval and adults stages. It is introduced to impact mealybug populations. Its larvae resemble a mealybug but are about twice as large as the adult citrus mealybug females. The adult is a small beetle with dark brown wing covers and a light brown head and prothoracic shield. It does not winter well and therefore commercial releases are sometimes necessary where mealybugs were a problem the previous year.

Chemical:

Treatment is rarely required for mealybugs. If a heavy population of mealybugs must be reduced quickly, a treatment can be applied, but a follow-up treatment with a biological control agent would be useful.

- **Chlorpyrifos.** 21 day PHI. Chlorpyrifos (LORSBAN, DURSBAN) is a broad-spectrum insecticide applied at label rates to less than 0.1% of the state's acreage. No more than 2 applications/year may be made with at least 30 days between applications. Chlorpyrifos is toxic to bees and is not applied during daylight hours of bloom period. The reentry interval for chlorpyrifos is 24 hours.

BROWN GARDEN SNAIL

Helix aspersa

Damage. The brown garden snail is primarily a pest in nurseries. It is rarely a problem in mature groves where a natural leaf mulch is present. Until a mulch develops, there can be extensive damage to blossoms, leaves, and young fruit, particularly in wet springs.

Description of Pest. The brown garden snail is about 1 inch in diameter at maturity and has a distinct color pattern. It is most active during the night and early morning when it is damp. In southern California, particularly along the coast, young snails are active throughout the year. Mature snails hibernate in topsoil during winter (3).

CONTROLS

Cultural:

Mulch. The mulch creates a very loose, dry environment that the snails have a difficult time crawling over. There can be extensive damage to blossoms, leaves, and young fruit until a mulch develops particularly in wet springs. Leaf fall is left on grove floors to create a dry mulch environment that is not favorable to snails.

Copper Bands. As discussed under "chemical" controls, copper foil bands are placed around the trunk at a height of 1 to 2 feet above the ground. It is overlapped on the tree trunk for approximately 8 inches so it will slip and allow for trunk growth.

Limitation of Sprinkling. Frequent microsprinkler irrigations encourage brown garden snail populations, so growers extend the interval between irrigations as much as possible if snails are a problem. Growers skirt prune groves to reduce the avenues for canopy entry, trimming back any branches touching the grove floor (3).

Physical Barriers. Physical barriers can also suppress the introduction of the brown garden snail but this practice can be very expensive.

Biological:

Snails are a common problem in young groves.

Rumina decollata. The predatory decollate snail, *Rumina decollata*, has been used successfully in citrus groves, but takes 4 to 10 years to become established. They are commercially available and are used in some areas to start populations in avocado groves though these practices are currently rare. These snails may be released only in the following California counties: Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, Tulare, and Ventura. However, by 10

years, when *Rumina* becomes established, there should be sufficient leaf mulch to preclude the brown garden snail problem.

Chemical:

- **Metaldehyde.** 0 day PHI. In young groves, brown garden snail populations build in late winter and spring. Metaldehyde is applied to 3% of the state's avocado acreage. If cultural practices do not keep snails at sub-economic levels, it may be necessary to apply metaldehyde bait to reduce populations, especially during wet springs. Metaldehyde bait is applied at a rate of 20 to 40 lbs ai/acre. The higher rate may be needed for heavy infestations or during wet weather. There is no restricted reentry interval for metaldehyde.
- **Copper Bands.** 0 day PHI. Copper foil bands are placed around the trunk at a height of 1 to 2 feet above the ground. It is overlapped on the tree trunk for approximately 8 inches so it will slip and allow for trunk growth. No restricted reentry interval.

JUNE BEETLES (Scarabs)

Coenonycha testacea, Serica

Damage. June beetles are most injurious in young groves planted near uncultivated land. They fly in from untilled fields and brushland and eat the foliage on the trees at night. June beetles can completely defoliate hundreds of trees in a single grove. During the day, they burrow into the soil to a depth of up to 2 inches (5 cm), reappearing the following night to resume feeding.

Description of Pest. Of the June beetles attacking avocados, the species *Serica fimbriata* and *S. alternata* are the most common and widely distributed. Adults of both *Serica* species are large and robust. *Serica fimbriata* is 0.6 inch (1.5 cm) and *S. alternata* 0.36 inch (9 mm) long. The former is a velvety brown with faintly striated wing covers, while the latter is a uniform shiny brown color. *Coenonycha testacea* is smaller and distinctly more narrow (almost rectangular) than the other two. It is about 0.36 inch (9 mm) long and shiny brown. The grubs of all three species are C-shaped, cream colored, about 1 inch (2.5 cm) long, and live in the soil where they feed on roots. June beetles have one generation per year.

CONTROLS

Cultural:

Blacklights. Growers sometimes use blacklights to trap beetles in small plantings. There is a risk, however, of attracting adult beetles from outside the grove (3).

Biological:

There are no identified biological controls specific to June beetles.

Chemical:

- **Malathion.** 7 day PHI. Foliar applications are made at night when beetles are feeding in the trees. Malathion is applied at an average rate of 0.5 lb ai/acre to less than 0.5% of the avocado acreage. Malathion disrupts biological control of other pests such as scales, thrips, mites, and whiteflies. The restricted reentry interval is 12 hours.

FALSE CHINCH BUG

Nysius ericae

Damage. Young avocado trees have been attacked and severely injured by these insects, which suck sap from stems. Graphing points are also susceptible. Affected plants wither and die suddenly after attack. Avocado groves adjacent to grasslands are particularly vulnerable in May and June when grasses dry out (3).

Mature trees are little affected by false chinch bugs and groves located away from grasslands are rarely affected. Young trees near foothills can be severely affected and may require chemical treatment, especially along the grove borders.

Description of Pest. The false chinch bug is a small, light or dark gray bug. Pale gray nymphs have reddish-brown abdomens and swarm from dry grasslands into adjacent cultivated areas. There are from four to seven generations per year (3).

Monitoring. Monitoring is often difficult because of nighttime activity of this pest.

CONTROLS

Cultural:

Weed and Grass Control. When possible, growers eliminate weeds and grasses near groves that may harbor false chinch bugs.

Biological:

There are no biological controls that specifically impact false chinch bug.

Chemical:

Treatment for false chinch bug is usually limited to protection of young trees and recently grafted trees.

- **Malathion** 7 day PHI. Malathion is applied at average rates of 0.5 lb ai/acre. It is applied as a foliar spray to infested trees. Use of this material will disrupt biological control of other pests such as scales, thrips, mites, and whiteflies. Malathion is applied to less than 0.5% of the avocado

acreage. The restricted reentry period is 12 hours.

- **Narrow Range Oil.** 0 day PHI. Narrow range oils are applied at label rates and require good coverage to be effective. It can effect bloom and should not be applied to young fruit. The oil does kill some beneficial insects, particularly early in the season. It is an inexpensive treatment but provides somewhat variable results. Oils are applied to about 5% of the state's acreage. The restricted entry interval is 4 hours.
- **Azadirachtin.** 0 day PHI. Azadirachtin (NEEM OIL) is applied at label rates and has demonstrated variable effectiveness and high costs. The restricted entry interval is 4 hours.
- **Carbaryl.** 5 day PHI. Carbaryl (SEVIN) is a carbamate. It is a broad-range insecticide that can be used to treat several insect pests. It is rarely used by the avocado industry because it is a harsh chemical that can have disruptive effects on the balance with beneficial predators. No material was applied in 1996. It should not be applied during bloom as it is toxic to bees. Carbaryl may be applied in combination with narrow range oil at reduced rates which increases the survival of natural enemies and reduces the risk of phytotoxicity. The restricted entry interval for carbaryl is 12 hours.
- **Pyrethrin plus Rotenone.** A combination product (PYRINONE) containing pyrethrin and rotenone is applied at label rates for control of false chinch bugs. It has been shown to be variable in effectiveness. The restricted entry interval is 12 hours.
- **Pyrethrins and Piperonyl Butoxide.** A combination product containing pyrethrins and piperonyl butoxide is applied at label rates to avocado groves to control false chinch bugs. The effectiveness of this product on this pest has been variable. The restricted entry interval is 4 hours.

FULLER ROSE BEETLE

Pantomorus cervinus

Damage. Although not common, Fuller rose beetle can be a problem in young plantings of avocado. The beetle can also be a problem in recently grafted trees since these trees have limited canopy. The beetles feed on leaf margins, causing a ragged, notched, or serrated appearance. This type of injury is commonly observed on the lower branches of trees. With large trees, feeding damage is not economically important. This is especially true in recently top-worked groves where the foliage on new grafts is limited (3).

Description of Pest. Adult Fuller rose beetles are brown snout beetles (weevils), grayish brown in color. Female beetles lay their eggs in clusters of several dozen in crevices on the tree or under loose bark. Upon hatching, larvae drop to the ground, and may feed on tree roots if other food, such as the roots of weeds, is not available. There is only one generation each year, with overwintering grubs pupating from May to July. Adults begin emerging in June, but most emerge in August and September.

Monitoring. Starting in June, growers watch for telltale leaf notching symptoms made by newly emerged adults. On young trees, chemical treatment may be warranted if damage is substantial.

CONTROLS

Cultural:

Sticky Barriers. Sticky barriers are sometimes placed around young tree trunks, but must be placed over a layer of tape to protect the tender tree trunks from damage. In the hot weather, sticky materials may run off the tape and contact tender trunk tissue leading to sunburn. This control method is not a common practice.

Biological:

***Fidiobia citri*.** The egg parasitoid, *Fidiobia citri*, can parasitize up to 50% of the Fuller rose beetle eggs. Parasitized eggs are darker in color than healthy eggs and may persist long after unparasitized eggs have hatched.

Chemical:

- **Malathion.** 7 day PHI. Malathion is applied at a rate of 0.5 lb ai/acre to less than 0.5% of the avocado acreage. Malathion disrupts biological control of other pests such as scales, thrips, mites, and whiteflies. It is not very effective against Fuller rose beetle. The restricted reentry period is 12 hours.
- **Carbaryl.** 5 day PHI. Carbaryl (SEVIN) is a carbamate. It is a broad-range insecticide that can be used to treat several insect pests. It is rarely used by the avocado industry because it is a harsh chemical that can have disruptive effects on the balance with beneficial predators. No material was applied in 1996. It should not be applied during bloom as it is toxic to bees. Carbaryl may be applied in combination with narrow range oil at reduced rates which increases the survival of natural enemies and reduces the risk of phytotoxicity. The restricted entry interval for carbaryl is 12 hours.

ORANGE TORTRIX

Argyrotaenia citrana

Damage. Orange tortrix is an occasional problem on avocados grown in coastal areas and is rarely injurious in inland growing areas. The most frequent injury caused by orange tortrix occurs on terminal twigs in the outer canopy of the tree. Larvae feed on green bark and often girdle twigs. The injured area may be covered by white exudates from wounds. Large twigs may be girdled at the point of their attachment to larger branches.

While not as common as terminal twig feeding, fruit feeding by larvae is much more serious because it reduces yield. The injury is similar to that of the other avocado worms except that orange tortrix may make deeper holes. Orange tortrix will feed near the stem end of fruit and on the stem, causing fruit drop (3).

Description of Pest. Orange tortrix's life cycle and damage are similar to that of the other avocado worms (omnivorous looper and amorbia). They are usually found in young tips of twigs among unfolding leaves that they web together. They may also make nests among buds or blossoms. Larvae feed on plant parts enclosed by webbed leaves. Orange tortrix has four to seven generations per year. During the bloom period, tiny larvae may be found inside the flowers, where they feed on developing fruit or the calyx. The same larvae may later form a nest of several flower heads and feed on the flower bases or on the stems of flower clusters.

Monitoring. In coastal areas growers monitor orange tortrix larvae throughout spring and summer at 7- to 10-day intervals looking for orange tortrix larvae and evidence of parasitism primarily on the south and east quadrants of trees.

CONTROL

Cultural:

Pruning and Thinning. Growers reduce avocado worm populations to sub-economic levels by pruning and thinning the grove to reduce dense foliage and interlacing branches that form a continuous canopy.

Biological:

Several parasites and predators attack orange tortrix.

Parasites. The most common parasites are two wasps, *Apanteles aristoteliae* and *Exochus* sp. These wasps lay their eggs in tortrix larvae and the parasites develop within. *Apanteles* pupates in white cocoons outside dead larvae. *Exochus* pupates inside larvae and emerges through a round exit hole.

Predators. *Trichogramma* sp. occasionally attacks egg masses.

Chemical:

If sprays are needed, use when larvae are small. Spraying with malathion, methomyl or carbaryl often leads to outbreaks of other pests and is not recommended.

- ***Bacillus thuringiensis* subsp. *kurstaki*.** 0 day PHI. *Bacillus thuringiensis*, subsp *kurstaki* (DIPEL) is effective when used to control early instars of the worm. The restricted entry interval is 4 hours.
- **Methomyl.** 1 day PHI. Methomyl (LANNATE) provides variable effectiveness when used at label rates. Treatment with methomyl is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Methomyl is an oxime carbamate. It is applied at a rate of 0.75 lb ai/acre to less than 0.5% of avocado acreage. Methomyl has a restricted entry interval of 48 hours.
- **Malathion.** 7 day PHI. Treatment with malathion is not recommended because it will kill natural predators and may lead to outbreaks of other pests. Malathion is an organophosphate. It is applied at a rate of 0.5 lb ai/acre to less than 0.5% of avocado acreage. It has a restricted entry interval of

12 hours.

Diseases

Disease Control in California Avocados. The California Avocado industry uses very little chemical fungicides. For example, in 1996, the most recent year compiled by the state of California, chemical fungicides were used on less than 2% of the state's avocado acreage. This contrasts with many other commodities in the state, where essentially all of the production acreage is treated with one or more fungicides during the season. Though the economic impact of diseases to avocado production in California is quite limited, so is the availability of pest management tools to the industry. Fungicides are used on less than 1% of the acreage but this limited use is crucial for the viability of these acres. Because the scope of use of fungicides is limited in California and because so few fungicides are approved for use on avocados, the maintenance of these registrations is essential to the industry and of no serious consequence to the "risk cup" calculations under FQPA.

AVOCADO ROOT ROT

Phytophthora cinnamomi

Damage. Avocado root rot is the most serious disease of avocados in California. Infected trees will decline and die. The disease spreads from tree to tree within the grove.

Symptoms. Foliage of infected trees is sparse. Leaves are small, pale green and often wilted. New growth is usually absent, but when present are small and of poor color. Small branches die back in the top of the tree allowing other branches to become sunburned. Diseased trees frequently set a heavy crop of small fruit. Small feeder roots are usually absent on diseased trees. If present, these roots are blackened, brittle and dead. The absence of feeder roots prevents the uptake of moisture and the soil under diseased trees stays wet. The disease does not typically affect roots of pencil size or larger.(4)

Avocado root rot is readily spread through groves by anything coming into contact with contaminated soil: by moving contaminated nursery stock or other plants; in water moving over or through soil containing the fungus, on equipment or workers shoes, in seeds from fruit lying on infested soil.

CONTROL

Cultural:

Fertilizer Nutrients. The use of fertilizers, particularly phosphoric treatments, can secondarily assist in controlling phytophthora infestation.

Field Selection and Irrigation. Growers select fields with soils that drain well. Accumulated moisture permits the fungus to form its spore stages and to infect the roots. Careful irrigation in infected areas can retard the spread of the disease, prolonging the life of infected trees. Since diseased trees have fewer roots to take up the water, these trees require less frequent irrigation. To prevent the spread of infection, growers install water-tight drains to take care of surface runoff if a diseased area lies above a healthy grove.

Tolerant Rootstocks and Disease Free Nursery Stock. In areas where root rot is a problem, growers plant with stock (Duke 7, Thomas and G755) that is tolerant to root rot. Certified disease free trees are available from nurseries that participate in the certification program.

Barrier. When the disease occurs in only one area of the grove and does not present a threat of spreading downhill in surface runoff or drainage, a physical barrier (i.e. fence and warning signs) is established two to three rows beyond the infected area to remind workers of the threat of infection and to inhibit movement between the root rot area and healthy sections of the grove.

Nursery Placement. In areas where trees have been removed, replanting soil to resistant crops is an effective control of root rot. Some plants that are not susceptible to root rot include citrus, cherimoya, persimmon, all types of vegetables, most annual flower crops and some deciduous fruit trees and berries.

Chemical:

Treatment of avocado root rot has changed in recent years. Metalaxyl (RIDOMYL) is no longer available for field use and has largely been replaced by the chemically related mefenoxam (RIDOMYL GOLD). In addition, use of fertilizers can help suppress avocado root rot, resulting in decreased use of conventional fungicides.

- **Fosetyl-Al.** 0 day PHI. Fosetyl-al (ALIETTE) is applied at label rates to affected areas to slow the progress of the disease. Fosetyl-al is applied to less than 2% of avocado acreage at an average rate of 1.25 lbs ai/acre. The restricted reentry interval is 12 hours.
- **Mefenoxam.** 28 Day PHI. Mefenoxam (RIDOMYL GOLD) has recently become available for fungicidal use in avocados. The ingredient is a reduced-risk substitute for the chemically related metalaxyl (RIDOMYL). Mefenoxam is applied at rates ranging from 0.04 lb ai to 4.5 lb ai/acre, dependent on the size of the tree canopy. There is no information available yet on the extent of mefenoxam's use since it is a recently registered active ingredient in California. The restricted reentry period is for mefenoxam is 12 hours.
- **Copper Hydroxide.** 0 day PHI. Copper hydroxide is applied at label rates to affected areas to slow the progress of the disease. It is used on less than 0.1% of the state's acreage at an average rate of about 4 lbs ai per acre. The restricted entry interval is 48 hours.
- **Methyl Bromide.** When only a few trees are affected, the trees are cut off at ground level and the soil fumigated with methyl bromide at the highest labeled application rate. The primary use has been for avocado nurseries. In 1995 and 1996, only 0.01% of avocado groves were treated with methyl bromide, primarily as a pre-plant treatment for new groves. Methyl bromide is applied

only by permit from a county agricultural commissioner. Methyl bromide is being phased out.

PHYTOPHTHORA CANKER (COLLAR ROT)

Phytophthora citricola

Damage. Phytophthora canker, or collar rot (also known as crown rot), is widespread in California attacking many avocado trees and is second only to Avocado Root rot in severity. In some areas, 80% of the trees are affected. Affected trees gradually lose vigor and decline. In advanced stages of the disease, the trees die.

Symptoms. Phytophthora canker is spread by contact on contaminated nursery material, through irrigation, on equipment and by people. Trunk cankers are found on the trunk base of older trees originating at or below ground level. Cankers appear as dark regions which exude a red resin that on drying turns into a white crystalline deposit. Removal of the canker reveals an orange-tan to brown pigmented lesion, instead of the normal white or cream-colored tissues. Lesions may spread in the crown roots and proceed into the bark of the trunk. Phytophthora canker has been found to exist on trees for years leading to the gradual decline in the tree. However, in some trees the disease progresses quickly, killing the trees in a couple of months.

Monitoring. Growers confirm the *Phytophthora citricola* infection by laboratory tissue isolations onto selective media.

CONTROL

Cultural:

Field Selection and Irrigation. Growers select fields with soils that drain well. Accumulated moisture permits the fungus to form its spore stages and to infect the roots. Growers irrigate the grove in a manner intended to keep the lower trunk dry for long periods. Drippers are placed away from the trunks and mini sprinklers are aimed to avoid wetting the trunks. Careful irrigation in infected areas can retard the spread of the disease, prolonging the life of infected trees. To prevent the spread of infection, growers install water-tight drains to take care of surface runoff if a diseased area lies above a healthy grove.

Tolerant Rootstocks and Disease Free Nursery Stock. Seedling rootstocks are more sensitive to Phytophthora canker than most clonal varieties. Duke 7 and 9, Barr Duke, 755A and Toro Canyon varieties have shown some tolerance to the disease.

Barrier. When the disease occurs in only one area of the grove and does not present a threat of spreading downhill in surface runoff or drainage, a physical barrier (i.e. fence and warning signs) is established two to three rows beyond the infected area to remind workers of the threat of infection and to inhibit movement between the diseased area and healthy sections of the grove.

Chemical:

Fosetyl-Al. 0 day PHI. Fosetyl-al (ALIETTE) is applied at label rates to affected areas to slow the progress of the disease. Fosetyl-al is applied to less than 2% of avocado acreage at an average rate of 1.25 lbs ai/acre. The restricted reentry interval is 12 hours.

DOTHIORELLA CANKER

Dothiorella gregaria

Damage. Dothiorella canker is a less serious type of canker and causes little economic damage. Dothiorella canker is a more significant disease during wet years.

Symptoms. A white powder exudes from the tree bark and the outer bark sometimes cracks and sheds. Affected trees sometimes die back and in severe cases may die.

Monitoring. Dothiorella is a latent disease. The disease is hard to predict until the infestation is already underway.

CONTROL**Cultural:**

Irrigation. The disease is favored by moist conditions. The grove is prepared and irrigation managed to avoid over watering and/or standing water. Dead leaves and debris are removed from around the trunks to eliminate moisture to the trunks.

Scraping. When lesions are abundant, growers scrape the outer bark to remove some of the infection and encourage regeneration of vigorous bark.

Chemical:

Chemical control for this disease is not typically needed.

- **Copper Hydroxide.** 0 day PHI. Copper hydroxide, though potentially effective, would have to be applied before a wet season was coming. Copper hydroxide would be applied at labeled rates. The restricted entry interval is 48 hours.

PHYTOPHTHORA FRUIT ROT

Phytophthora citricola

Damage. This disease is of minor importance in California, but may cause some damage during wet, prolonged weather. Phytophthora fruit rot effects the fruit while it is still hanging on the tree, causing circular black areas at the lowest spot on the fruit. Diseased fruit are downgraded and sometimes not

marketable.

Symptoms. Affected fruit are typically on lower branches within 1 meter of the ground or are touching the soil. Circular black areas appear on the lower part of the fruit. The infection extends into the flesh of the avocado, darkening it in the same pattern as the affected areas on the surface. Infection is probably caused by the splashing of the *Phytophthora citricola* spores that cause Phytophthora canker.

CONTROL

Cultural:

Field Management Practices. To prevent the splash from heavy rains or external sources, tree skirts are trimmed one meter from the ground. Ground cover or mulches, such as leaves, may be left on the ground to help control splashing. Fruit lying on the ground are removed because fungus can grow and sporulate on them.

Chemical:

There are no chemicals labeled for this disease on avocados.

DOTHIORELLA FRUIT ROT

Dothiorella gregaria

Damage. Dothiorella Fruit Rot is a minor post-harvest problem of avocados in California. Infected fruit discolors the avocado flesh and develops an offensive odor.

Symptoms. The symptoms of this disease do not appear until after the fruit has been harvested and begins to soften. Small purplish-brown spots appear on the fruit, typically at the stem end. These spots enlarge and may involve the entire fruit surface. The flesh becomes discolored and develops an offensive odor.

CONTROL

Cultural:

Field Management Practices. Dead materials, such as leaves, twigs and branches, are removed from the groves. Saline conditions, which induce leaf-burning, are avoided as the fungus will live on the dead portions of the leaves.

Post Harvest Handling. Fruit are cooled to 41F soon after harvest. Delays of longer than 6 hours before cooling and higher pulp temperatures will result in increased postharvest fruit decay.

ANTHRACNOSE

Colletotrichum gloeosporioides

Damage. Anthracnose is a natural inhabitant of the California avocado groves where it grows on dead twigs and leaves and is usually of little importance. It is not typically a problem of avocados in California though the disease often follows wet winters. During extended periods of rainfall, the fungus builds up and may become a serious problem. The disease can cause fruit infection that can be extensive but does not appear until the fruit begins to ripen after harvest. Fruit infected with this disease may be downgraded or not marketable. (4)

Symptoms. Trees infected with anthracnose lose their leaves. Leaves may have large, brown, dead areas appearing in the center and on their margins. Once deposited on the undamaged, green fruit surfaces, the spores germinate and penetrate the fruit causing small black or brown spots. There is no further development until the fruit ripens at which time the fungus resumes its growth producing visible symptoms. The fungus may enter the fruit via wounds caused by insects and other pathogens. These spots enlarge, sometimes covering the entire fruit. The flesh of the avocado is rotted and gray brown in hemispherical patterns around the disease entry. (4)

CONTROL

Cultural:

Field Management Practices. To ensure rapid drying of the foliage after rains, foliage is pruned on lower limbs so that the canopy is at least 20 inches above the ground allowing for good ventilation. Dead twigs and branches are pruned and dead leaves entangled in the tree canopy are removed. Infected fruit that have not fallen off the tree are removed. Insects, which puncture or damage the fruit allowing the fungus infection to enter, are controlled.

Post Harvest Handling. Fruit are cooled soon after harvest. Delays of longer than 6 hours before cooling and higher pulp temperatures will result in increased postharvest fruit decay.

Chemical:

- **Copper Hydroxide.** 0 day PHI. Copper hydroxide is applied at label rates to affected areas to slow the progress of the disease. It is used on less than 0.1% of the state's acreage at an average rate of about 4 lbs ai/acre. The restricted entry interval is 48 hours.

ARMILLARIA ROOT ROT

Armillaria mellea

Damage. Armillaria root rot causes a gradual deterioration in tree vigor, yellowing foliage and leaf drop over part or all of the tree, with sudden wilting and collapse. Death of the tree usually follows. (4). The disease is worst in wet years. Avocado trees are resistant to armillaria, relative to most commercial tree crops.

Symptoms. A white, fan-shaped growth of the fungus mycelium under the bark of diseased roots is a sign of Armillaria root rot. Purplish-brown cord-like rhizomorphs that resemble feeder roots sometimes grow on the surface of diseased roots. The Armillaria fungus may produce mushrooms around the base on the affected tree during the fall and winter when conditions are wet.(4)

Armillaria root rot spreads in infested wood and soil, leaf mulch under infected trees, by flood water washing over infected wood or mulch, by equipment or any other carrier that comes into contact with the infected wood or soil. The fungus moves through the grove from one tree to another by growing along diseased roots and infecting healthy roots of adjacent trees. When infected or dead trees are removed from the grove, the fungus continues to live in any roots remaining in the soil.

CONTROL

Cultural:

Tree Removal. The most typical treatment for armillaria is to remove the infested tree from the grove. Attempts at complete removal of the affected root system are important.

Air Drying. Armillaria root rot is sensitive to drying. Growers expose the base of the tree to the air.

Chemical:

- **Methyl Bromide.** Prior to planting, the area is fumigated with methyl bromide and covered with tarps. Soil fumigation has successfully controlled Armillaria root rot. In 1995 and 1996, only 0.01% of avocado groves were treated with methyl bromide. Methyl bromide is applied by permit from a county agricultural commissioner. Methyl bromide is being phased out and there are no chemical alternatives available for treatment of armillaria.

AVOCADO BLACK STREAK

Damage. Avocado black streak (amyelplasmid/viroid) infects Guatemalan varieties of avocado, typically appearing after prolonged periods of environmental or cultural stress. The affected tree declines, has poor fruit production and may eventually die. Avocado black streak is a disease of poor grove management.

Symptoms. Trees infected with Avocado Black Streak display symptoms including chlorosis, early bloom, branch die-back, leaf blotching, zinc deficiency, bunched growth, wilting and rapid death of new growth. Cankers on the trunk and branches appear on infected trees. The canker is characterized by an accumulation of a dry, powdery, water soluble sugar that exudes through minute cracks in the bark. Cankers may range in size from very small to most of the trunk. Scraping the bark surface over the cankers reveals shallow, reddish-brown areas that typically do not extend into the cambium.

CONTROL

Cultural:

Maintaining Plant Health. Since Avocado Black Streak affects stressed trees, maintaining the health of the trees is the best management practice. Trees are fertilized and appropriately watered to prevent stress. Unhealthy trees are removed from the grove. The primary control of avocado black streak is to avoid poor maintenance of the grove.

Chemical:

There are no viable chemical treatments available for avocado black streak.

VERTICILLIUM WILT

Verticillium albo-atrum

Damage. Verticillium Wilt is not a common disease in California avocados but it can be serious disease. Although it will impact the health and productivity of the affected tree, trees often recover from the disease.

Symptoms. The fungus enters the roots of trees and invades the water conducting system, preventing water movement to the foliage. The leaves wilt on the affected part of the tree, turn brown and die, remaining attached for several months. Streaks of brown to grey are seen in the wood of the branches or roots where the bark is peeled. Affected trees often send out new, vigorous shoots within a few months after the initial collapse of the tree and the tree recovers completely. The disease is most common with peppers and eggplants.

CONTROL

Cultural:

Field Selection. Growers avoid planting on land that has been used for other susceptible crops, such as tomato, eggplant, pepper, apricot, potato, some berries and flower crops. Susceptible crops are not planted in established avocado groves.

Chemical:

Chemical treatment is not typically needed, however, in cases of severe and recurring disease, removal of the affected trees may become necessary and the area is treated with a fumigant before replanting.

- **Methyl Bromide.** Prior to planting, the area is fumigated with methyl bromide and covered with tarps. In 1995 and 1996, less than 0.01% of avocado groves were treated with methyl bromide. Methyl bromide is applied by permit from a county agricultural commissioner.
- **Metam Sodium.** Metam sodium is not as effective as methyl bromide but a viable alternative once methyl bromide is phased out.

SUNBLOTCH

Avocado Sunblotch Viroid (ASBVD)

Damage. Avocado trees with visible sunblotch symptoms typically have reduced yields. The most important impact of sunblotch is the impact of the disease on the export of fruit since the presence of this disease triggers restrictions in some countries. The disease is becoming increasingly common.

Symptoms. Narrow yellow, red or necrotic streaks appear on twigs. Fruit may have white or yellow blotches or streaks that may or may not be depressed. At maturity, fruit that remains green usually have white or yellowish areas, while fruit that turns black will have whitish areas that turn red. Leaves may have white or yellowish variegated areas and are often deformed, but this symptom is rare in the field. Trees affected by the disease are often stunted (4). ASBVD is carried in the host tissues. Some trees do not show symptoms, but have reduced yields.

CONTROL

Cultural:

Registered Stock. Since this viroid is carried within host tissue, growers use registered trees of disease-free scions and seed sources.

Field Management Practices. Trees that have symptoms are sometimes removed from groves and the remaining stumps killed. Pruning tools and harvest clippers are sterilized between trees.

BACTERIAL CANKER

Xanthomonas campestris

Damage. Bacterial canker is a widespread, but minor disease. Within a normal grove, there are typically several affected trees. In some groves, the disease may be severe and affect over 50% of the trees.

Symptoms. The tree bark darkens and becomes slightly sunken with a watery, necrotic pocket under the surface. As the canker develops, the bark splits and the fluid oozes out and dries leaving a white powdery residue around and sometimes over the lesion. Cankers usually appear at the base of the tree first and then spread upward in a straight line on one side of the trunk. Streaks extend up and down in the wood from the necrotic areas underneath the cankers.

CONTROL

The disease is a minor problem and no control is necessary. If the disease is severe and the yield is affected the tree is removed from the grove.

Nematodes

ROOT LESION NEMATODE

Pratylenchus vulnus

Damage. Nematode problems in California avocado groves are not very common. They are rarely treated. Nematode infestations rarely justify specific controls though sometimes efforts to suppress populations are performed during pre-plant periods in groves. Root lesion nematode infestations have been observed only in Ventura County avocado groves that were previously planted adjacent to walnuts. Infested trees appear stunted with very few feeder roots, and may be more susceptible to frost injury. These symptoms are indicative of root lesion nematode problem, but are not diagnostic as they could result from other causes as well.

Description of Pest. Plant parasitic nematodes are microscopic, unsegmented roundworms that live in soil and plant tissues and feed on plants by puncturing and sucking the cell contents with a spearlike mouthpart called a stylet. The only plant-parasitic nematode observed in avocado groves and found to be pathogenic is the root lesion nematode, *Pratylenchus vulnus*.

Monitoring. If the trees are displaying symptoms and no cause is evident, growers sample the grove to determine if root lesion or other plant-parasitic nematodes are present by taking soil samples from within the root zone (6-36 inches deep) which are analyzed at a laboratory by extracting and identifying nematodes.

CONTROLS

Cultural:

Sanitation. Good sanitation practices are important to avoid infestations. Certified nematode-free materials are used by growers for planting.

Chemical:

When planting a new grove, the nematode infestation history of the site will indicate whether a preplant fumigation is needed to reduce nematode population levels. Trees planted on fumigated grove sites are generally known to have improved growth and yields compared to those on nonfumigated sites.

- **Methyl Bromide.** Methyl bromide is a broad spectrum material that controls weeds, soil fungi, and soil insects, as well as nematodes. Methyl bromide is applied either in a broadcast fumigation using tarps or a fumigation of the soil inverting the top 12 inches of soil with a reapplication 14 days later. It was applied to only 5 acres in 1995, less than 0.0001% of the treated avocado acreage. Methyl bromide may only be applied by permit of the county agricultural commissioner.

- **Metam Sodium.** Metam sodium is a broad-spectrum material that controls weeds, soil fungi, and soil insects as well as nematodes. Metam sodium was used to treat only 1 acre of avocado grove in 1995. It can provide effective control of nematodes if applied properly, but is a labor intensive material to use in order to achieve the needed soil penetration. Prior to application the field must be thoroughly cultivated to break up clods and deeply loosen the soil. Approximately 1 week prior to application, the field is preirrigated with 6 to 8 inches of water. After treatments, plantings cannot occur for 30 or more days. Only one application of metam sodium was reported for avocados in 1996.

Weeds

Overview. Weed management in and around avocado groves requires a combination of cultural practices and herbicide applications. Weeds harbor insect and vertebrate pests and compete with trees for water and soil nutrients. Newly planted groves are more susceptible to weeds as optimum conditions, abundant sunlight and irrigation, are present for seed germination and growth. Most weeds invading the grove are annuals.

CONTROLS

Cultural:

Field Management Practices. Mature trees with large canopies shading the grove floor present less optimum conditions for weeds. Leaves from mature trees form a natural dry mulch on grove floors which helps to control weeds. Timely removal of weeds is essential to minimize competition. In young groves, weeds are controlled mechanically by mowing between rows or with mulches. Examples of organic mulches include wood shavings, chopped straw and rice hulls.

Chemical:

Postemergent herbicide use is common for weed control though preemergent herbicides are also commonly used. The following herbicides are the most common (in order of acres treated):

- **Glyphosate.** 0 day PHI. Glyphosate (ROUNDUP) is a postemergent herbicide applied at 1 lb ai/acre to approximately 66% of treated avocado acreage to control annual weeds. The restricted entry interval for glyphosate is 12 hours.
- **Simazine.** 0 day PHI. Simazine is a preemergent selective herbicide that is applied at label rates to soil to control annual broadleaf weeds and grasses. It is applied to approximately 25% of treated avocado acreage. The restricted entry interval for glyphosate is 12 hours.
- **Oxyfluorfen.** 0 day PHI. Oxyfluorfen (GOAL) is a diphenyl ether compound applied as a preemergent or a postemergent herbicide to control annual weeds. Applications to weeds beyond the 4 leaf stage may result in poorer control. It is applied at label rates to about 2% of avocado

acreage. There is no restricted reentry interval.

- **Norflurazon.** Norflurazon is a pre-emergent triazine herbicide used to control grasses and broadleaf weeds. It is applied at 1 lb ai/acre to about 1.5% of California's avocado acreage.
- **Oryzalin.** 0 day PHI. Oryzalin (SURFLAN) is a preemergent herbicide applied to the soil at label rates to control annual grasses and certain broadleaf weeds. It is applied to less than 1% of treated avocado acreage. There is no restricted reentry interval.

Vertebrate Pests

Overview. A number of vertebrate species live within or move into avocado groves for food or shelter. The potential for damage by vertebrates varies from grove to grove and region to region. Vertebrate pests can often assist root rot within the grove. Groves located near rangeland, wooded areas or other uncultivated areas are more likely to be invaded or reinvaded by certain vertebrates. Predators, diseases and food sources all may influence a vertebrate populations. Predators such as coyotes, foxes, snakes, hawks and owls feed on rodent and rabbit species. Growers cannot, however, rely on predators to prevent rodents or rabbits from becoming agricultural pests.

POCKET GOPHER

Citellus spp.

Damage. Pocket gophers are important vertebrate pests. They gnaw on the root systems and girdle young trees below the soil line. Their burrows run through the grove, diverting water and contributing to soil erosion and the spread of fungal diseases.

Description of Pest. Rarely seen, gophers spend most of their time underground, but can be identified as present in the grove by the characteristic crescent-shaped mounds of soil indicating their burrows. In the fall, winter or spring when the soil is moist from rain, pocket gophers increase their digging activity and fresh mounds appear.

Monitoring. Growers monitor for gophers by looking under tree skirts especially near the border of the grove where gophers may move in from adjacent fields or groves. Gophers should be controlled as soon as they are detected.

CONTROL

Cultural:

Trapping and Baiting. Trapping or baiting by hand are the most effective control mechanisms. Traps are placed in the main tunnel between two fresh mounds. Growers check the traps daily. Pocket gophers

are classified as nongame mammals and can be eliminated at any time if injuring crops.

Chemical:

- **Strychnine.** Strychnine bait is applied at label rates to control gophers. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in the main tunnel. It is a restricted use material that may only be applied by permit from a county agricultural commissioner.
- **Diphacinone.** Diphacinone is a rodenticide bait intended to control gophers. It is applied at label rates. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in the main tunnel. Diphacinone is a restricted use material that may only be applied with permit from a county agricultural commissioner.
- **Aluminum Phosphide.** Aluminum phosphide is a phosphide fumigant that is used to control burrowing rodents. Fumigation of burrows does not work well because the burrow systems are extensive and gophers can quickly seal tunnels when they detect poisonous gas. Aluminum phosphide is a restricted use material and may only be applied with permit from a county agricultural commissioner.
- **Zinc Phosphide.** Zinc phosphide is a bait used to treat gophers and ground squirrels. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in the main tunnel. Zinc phosphide is a restricted use material and may only be applied with permit from a county agricultural commissioner.

CALIFORNIA GROUND SQUIRREL

Citellus spp.

Damage. Ground squirrels are a pest of groves digging burrows under the trees and gnawing on polyethylene irrigation hoses. In some areas, ground squirrels present a potential health hazard because they carry fleas which may transmit infectious diseases.

Description of Pest. Ground squirrels live in groups of up to 20 individuals. Although ground squirrels may not be seen, their burrows indicate their presence. Each burrow system has several openings which have scattered soil in front. Ground squirrels typically dig their burrows along ditches, fence rows and on uncultivated land, but may also establish burrows beneath trees in an grove.

Monitoring. Growers monitor for ground squirrels by checking the perimeter of the grove about once per month for animals or their burrows. If monitoring indicates that a squirrel population is moving into the grove, they can be controlled with traps, fumigants, or toxic bait.

CONTROLS

Cultural:

Trapping. Trapping ground squirrels works well in small areas or for a small number of squirrels. Growers check the traps daily. Ground squirrels are classified as nongame mammals and can be eliminated at any time if injuring crops. Tree squirrels, however, are classified as game mammals by the California Fish and Game Code and a permit from the local game warden is required for control of the eastern gray squirrel and poisoning of this tree squirrel is illegal. The eastern fox squirrel may also be eliminated in any manner if causing damage.

Chemical:

- **Strychnine.** Strychnine bait is applied at label rates to control ground squirrels. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed in traps and in burrows. It is a restricted use material that may only be applied with a permit from a county agricultural commissioner.
- **Aluminum Phosphide.** Aluminum phosphide is a phosphide fumigant that is used to control burrowing rodents. It works best in early spring when moist soil helps retain a high toxic gas level in the burrows. The burrows are checked after about three days. Where squirrels have dug out, retreatment is necessary. It is applied at label rates to less than 1% of treated acreage. Aluminum phosphide is a restricted use material and may only be applied with a permit from a county agricultural commissioner.
- **Diphacinone.** Diphacinone is an anti-coagulant rodenticide bait intended to control ground squirrels. It is applied at label rates to traps or in bait stations. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in the main tunnel. Diphacinone is a restricted use material that may only be applied with a permit from a county agricultural commissioner.
- **Zinc Phosphide.** Zinc phosphide is a bait used to treat ground squirrels. Zinc phosphide is a restricted use material and may only be applied with a permit from a county agricultural commissioner.

MEADOW MICE

Microtus spp.

Damage. Meadow mice, which are also referred to as voles or field mice, inhabit roadsides, meadows, canal banks, fencerows and many field crops. They are primarily a problem in young groves. Meadow mice are rarely a problem in weed-free groves, although some damage may occur at the edges bordering field crops or other preferred habitats. Young groves with some weed cover are more likely to have mouse populations, especially if established in former rangeland or uncultivated land. Meadow mice feed on young or mature trees, sometimes girdling the trees close to the soil line.

Description of Pests. Full-grown meadow mice are larger than house mice but smaller than rats. Well-established populations can be recognized by the network of small runways through the grass or other

cover and the openings of numerous shallow burrows. Meadow mice are active year round, day and night. Females bear four to eight litters each year with a peak production period in the spring. Uncontrolled populations fluctuate, reaching a peak every four to seven years, then declining sharply.

Monitoring. Growers monitor the grove in the fall or winter checking for signs of mouse activity. If treatment is necessary, treatments are most efficient before the spring breeding season.

CONTROL

Cultural:

General Field Management. Preventative measures may be taken by growers to make the grove less favorable to invasion by meadow mice and their survival. Growers clear weeds and thick mulches around tree trunks to discourage infestation by meadow mice. Weeds are also cleared from fencerows or ditch banks. If a groundcover is grown in the grove, growers keep weeds at least 3 feet from tree trunks. Meadow mice are classified as nongame mammals and may be eliminated in any manner at any time if they are injuring crops.

Tree Wrappers. Tree wrappers used for sunburn and frost protection offer some protection, although these wrappers sometimes offer shelter for the deer mouse or house mouse.

Chemical:

- **Diphacinone.** Diphacinone is an anti-coagulant rodenticide bait applied at label rates. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in an active runway, burrow entrance or at several spots around the trunks of trees. Diphacinone is a restricted use material that may only be applied with a permit from a county agricultural commissioner.
- **Zinc Phosphide.** Zinc phosphide is a bait used to treat meadow mice at labeled rates. Zinc phosphide is a restricted use material and may only be applied with a permit from a county agricultural commissioner.

BLACK-TAILED JACKRABBIT

Lepus californicus

The black-tailed jackrabbit is a common pest that may feed on the bark of young trees. Jackrabbits cause little damage to mature trees; however they may use the grove as shelter during the day then move out to forage on field crops during the night.

CONTROL

Cultural:

Tree Wrappers. Tree wrappers used for sunburn and frost protection offer some protection, although these wrappers sometimes offer shelter for the deer mouse or house mouse. Wire guards, 3 feet high, around tree trunks also help protect young trees from potential jackrabbit damage. Jackrabbits are classified as game mammals by the California Fish and Game Code. The hunting season is year round with no bag limit.

Trapping. When injuring crops, jackrabbits may be killed in any manner, but traps must comply with Fish and Game regulations and state law.

OTHER VERTEBRATE PESTS

RAT

Roof rat: *Rattus rattus*

Wood rat: *Neotoma* spp.

Damage. Roof rats are most common around dwellings, but also occur in groves. It is a problem in some areas of southern California. Roof rats build nests in trees. They may also chew the bark of scaffold limbs.

Description of Pest. Roof rats breed several time a year producing litters that average 6 young. They are most visible in border trees where they first establish themselves.

Wood rats are also called pack rats. They normally live in wooded or brushy areas. They feed on fruit or bark and cut twigs for their nests. Wood rats build their nests in trees within the grove.

CONTROL

Cultural:

Trapping. Trapping is effective for a small number of rats. Rat snap traps are attached to limbs and baited with raisins, prunes or nut meats. After feeding at the trap has been established, traps are set. Rats are classified as nongame mammals and can be eliminated in any manner at any time if injuring crops.

Chemical:

- **Diphacinone.** Diphacinone is an anti-coagulant rodenticide bait applied at labeled rates. Baiting by hand is one of the most effective control mechanisms. Single dose baits are placed in bait boxes. Diphacinone is a restricted use material that may only be applied with a permit from a county agricultural commissioner.
- **Zinc Phosphide.** Zinc phosphide is a bait used at label rates. Zinc phosphide is a restricted use material and may only be applied with a permit from a county agricultural commissioner.

DEER

Damage. Deer occasionally damage newly planted trees that are located near their natural habitats, such as woods and thickets. They feed at night on young tree foliage and rub their antlers on limbs in the spring.

CONTROL

Cultural:

Foliar Repellent. Foliar repellants may offer some protections, although fencing offers a more permanent solution.

Elimination. Deer are classified as game mammals by the California Department of Fish and Game. A depredation permit is needed for shooting deer that are damaging crops. Poisoning deer is illegal in California.

COYOTE

Canis latrans

Damage. Coyote can eat the irrigation tubing and structures.

CONTROL

Cultural:

Foliar Repellent. Foliar repellants may offer some protections, although fencing offers a more permanent solution.

Elimination. A permit is needed for shooting coyote that are damaging crops.

RESEARCH

Research areas for pest management in avocados focus on pests that are particularly problematic. Because pest management for California avocados is largely managed by cultural techniques and both natural and introduced biological control methods, the focus of research at any given time is limited to other commodities in the state. The following are current areas of pest management research.

Avocado Thrips. Avocado thrips have recently become a major economic pest to California avocados. In recent years, avocado thrips have resulted in significant decreases in yield and fruit grade. It is

estimated that growers have lost 35% to 45% market value. Fruit grade reductions lower the price received for avocados by 50%. Pest control options have been limited and no available pest management tool is sufficiently effective against avocado thrips without adversely impacting beneficial pest populations, leading to secondary insect infestations. Major research efforts are needed to develop an effective management process for this pest.

Persea Mite. Persea mite is a recently introduced pest of avocados. It occurs in most avocado-growing areas of California, except the Central Valley and is most damaging to the Hass variety of avocado (the major variety in California), but also attacks Gwen and Reed varieties. The early season damage caused by persea mite mainly affects the underside of the leaf and produces webbing along the midrib and veins. As persea mite populations increase, feeding causes leaf drop. A heavily infested tree will have a litter of yellow-spotted green leaves on the ground. Significant research is underway on introduction of new biocontrol predators such as *Neosileus californiacas*. Additional research is needed into other potential biocontrol methods and a continued search for a non-harsh chemical pesticide that can be registered on avocados.

Glassy-Winged Sharpshooter. The glassy-winged sharpshooter is a relatively new pest to California. Currently, it has only been found in Ventura County. It causes significant damage in several commodities. Though avocados are not significantly (economically) effected to date, there is a concern that the glassy-winged sharpshooter may be a vector of certain plant diseases. Although glassy-winged sharpshooter is a relatively new pest, it has increased substantially in recent years. Furthermore, no chemical controls are available to the avocado industry. Research is needed, possibly in conjunction with related research by the citrus and grape industries, to identify pest management options to control this increasingly serious pest.

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