Crop Profile for Apples in California

General Production Information

- Apple production in California represents 8.5% of the national production (1).
- California has over 38,500 bearing acres of apples (1).
- Yield per acre varies from 2 to 18 tons per acre throughout California’s growing regions, primarily due to irrigation and varietal differences (13).
- From 1995 to 1997, California apple growers average production was 920,000,000 pounds. In 1997, 962,000,000 pounds of apples were produced (1).
- The average value of apples produced in the state between 1995 and 1997 was $158,918,000. The value of apples produced in 1997 was $162,655,000 (1).
- The average cost to produce an acre of apples in California amounts to $4,523 per acre for irrigated orchards and $3,947 per acre for non-irrigated orchards (11, 12).

Production Regions

There are five major regions in which apples are grown in California. Historically, apple production was limited to the coastal mountains north and south of San Francisco Bay, in the Sierra foothills east of Sacramento, and in the Southern California mountains. Recently apple production has expanded into the Central Valley, with new plantings of Granny Smith, Fuji, Gala, and other varieties. Important coastal apple producing counties are Sonoma in the North Coast, and Santa Cruz and San Luis Obispo in the Central Coast region. However the major apple production areas are now in the San Joaquin Valley with Kern, Fresno, San Joaquin, and Madera counties being the leading producers (3). Southern California mountain regions still have a few orchards.

Cultural Practices

It is difficult to describe cultural practices in California because so many different systems are used depending primarily on where in the state apples are grown. California apple plantings vary widely. In the older apple growing regions, older orchards are often on standard rootstocks and widely spaced (50 to 108 trees per acre). Newer plantings are generally planted on size-controlling rootstocks with 180 to 500 or more trees to the acre. The trend is towards denser plantings of smaller trees.

In the North Coast region older varieties such as Red Delicious, Gravenstein, Rome Beauty, Golden Delicious, and Jonathan predominate. Most are planted on wide spacing and some in the Sebastopol area are not irrigated, although some newer orchards are close planted and irrigated. . European canker can be a major disease in this area and scab is a chronic problem because of extended rainy periods in spring (2).

In the Central Coast region Yellow Newtown and Red Delicious apples are the primary varieties grown. Although this is an older apple-producing region and many widely spaced orchards still exist, in the 1980s significant acreages of Granny Smith and other varieties were planted in high-density hedgerow orchards. Central Coast orchards are affected by orange tortrix and apple pandemis, which generally are not damaging elsewhere in the state. Apple scab and powdery mildew pressure is also high but codling moth pressure is somewhat lower in these areas than in other districts.

Both widely spaced and close planted orchards are present in the Sierra Foothills region. Yields are not as high in the Sierra Foothills as in the Central Valley, but because of the warm days and cool nights, the late-maturing fruit is high quality. Orchards in this region are irrigated and fruit is usually sold locally. Red Delicious, Golden Delicious, Rome Beauty, and Winesap are the predominant varieties grown in the Sierra foothills; although recently newer varieties have been planted.

Just over 1000 acres of apples are still grown at higher elevations in Southern California. Most of these are marketed locally. Major problems in this area are spring frosts and lack of adequate irrigation water.

Urban encroachment is a major problem in all of the above growing areas. Acreage is decreasing and will likely continue to decrease because of this and other problems.

About 60% of the apples planted in the state are now in the Central Valley, extending from Kern County in the south to Tehama County in the north. Because of the hot day and night time temperatures, this area is best suited to non-red varieties such as Granny Smith, Fuji, and Gala. Most of the trees have been planted since the late 1970s on size-controlling rootstocks. Many different training systems are used in this area. Fruit sunburn is a major problem and most of the systems attempt to alleviate this problem. The hot climate is conducive to fireblight development and insect pressure is severe because of the long growing season.

The lack of adequate chilling is sometimes a problem in California. This leads to extended bloom periods and "rat-tail" bloom that are favorable to the development of fireblight and makes chemical thinning of fruit difficult.

Apples in California are usually planted on well drained, sandy loam soils. Newer orchards are sometimes planted on berms to help alleviate drainage or shallow soil problems. Older widely spaced orchards are planted on standard rootstocks. Newer orchards are planted on size-controlling, semidwarf or dwarf rootstocks. Rootstocks and varieties vary widely in tolerance to diseases and insect problems. Often 2 or 3 different pollinizers are planted in an orchard, especially where lack of chilling and extended bloom may be a problem.

Although a few apple orchards in the North Coast are dry-farmed on, deep soils, yields and fruit size are usually smaller than in irrigated orchards. Various irrigation systems are used in California. Furrow or sprinkler irrigation is often used in older blocks. However, in newer plantings in the Central Valley, drip, mini-sprinklers, and sprinkler irrigation are most common. In the hotter areas, overhead sprinklers are installed in some blocks to provide frost protection in the spring and cooling on hot summer days.

Supplemental fertilization is usually necessary to re-supply the trees with adequate amounts of all essential nutrients. Most orchards receive annual applications of nitrogen. Zinc deficiency is fairly common in all apple growing districts and many blocks receive annual foliar applications of zinc. Potassium deficiency is found in some sandy soils and is corrected using potassium sulfate or muriate of potash. Phosphate fertilizers are also needed in the Sierra Foothills and coastal regions. Various growing regions also suffer from iron, copper, and calcium deficiencies which are corrected by foliar sprays or soil applications.

Trees receive annual pruning. Harvest in California varies according to variety. In the Central Valley, Gala and a few other varieties are harvested in July and later varieties such as Fuji are not harvested until late September or October.

Ground covers are commonly maintained in orchards, especially those growing in heavy, fine-textured soils. Ground covers may consist of volunteer annual plants or a planted annual or perennial cover crop. Often ground covers are allowed to grow in the summer which provides partial cooling for sunburn protection. Orchards planted on a berm practice down the row weed control with herbicides. Apples are thinned, either by hand or by chemicals. Stop-drop sprays are sometimes applied prior to harvest to prevent premature fruit drop (2).

Insect Pests

Major Insect Pests

Codling Moth,
Cydia pomonella

Codling moth is the key pest of apples and is the most economically important insect pest statewide. All the apples grown in the state are susceptible to codling moth and require three to six treatments every year with broad spectrum insecticides to prevent serious economic damage.

Codling moth attacks fruit directly and is responsible for the proverbial "wormy apple." Larvae bore directly into fruit. Infested fruit either drop from the tree or are culled at harvest. Codling moth overwinter as prepupae on the tree or in the soil around the base of the tree. In the early spring, adults emerge and lay eggs, giving rise to larvae that enter developing fruit. Fruit is susceptible to damage from petal fall until harvest. Adult codling moth are about ½ inch long, gray in color with a prominent copper spot on the end of the forewings. Codling moth larvae are whitish to pink in color with mature larvae being about 3/4 inch long. There are usually three generations per year in California's Central Valley, but a partial fourth generation may develop in warmer than normal years (2). Left uncontrolled, damage can exceed 60%.

Monitoring: Codling moth is monitored with pheromone traps, which are utilized to assess population levels and calculate degree days for timing treatments. Grade sheets from previous years are also utilized used to make treatment decisions (6).

Controls:

Biological:
Although over 250 biological control organisms have been shown to attack codling moth, none are capable of preventing economic damage.

Trichogramma platneri, a codling moth egg parasitoid, has reduced codling moth damage by up to 70% when 12 weekly releases of 150,000-200,000 per acre per week are released in low to moderate population situations (2). This level of control is not adequate to prevent economic damage in most apple orchards in the state.

Codling moth mating disruption has been demonstrated to be a viable alternative in California pear orchards, apples in coastal growing areas and other states where population pressure is low to moderate. However, due to high population pressure in the remainder of the state, mating disruption is more difficult. Nevertheless, a combination program of mating disruption plus supplemental insecticide treatments can significantly reduce the pesticide load in apples.

Attract and kill materials are under development and are registered for use. Research is continuing with these systems.

Codling moth granulosis virus has been shown to be somewhat effective. Larvae must ingest the virus and 9 to 12 applications are needed per season to cover the long generation time (6). Timing these treatments is difficult and irrigation scheduling prevents growers from getting into orchards in a timely matter. This material must be ingested to be effective and good coverage is important. No granulosis virus is currently registered in California.

Codling moth Granulosis Virus – 0 days PHI. Applied to less than one percent of the acres at an average rate of 0.73 lb. a.i. per acre (4). Availability of this material is limited.

Chemical:
Practically all apples in California are treated from 3 to 6 times (average about 4 times) during the growing season for codling moth. Because of multiple treatments in some blocks, the percentages given below will total over 100% .

- **Azinphos-methyl –** 14 days PHI. Applied, from 1-5 times postbloom, to 41% percent of the acreage by ground at an average rate of 1 lb. a.i. per acre (4). Some codling moth resistance has recently been documented in apples and pears in California (5). This is still a valuable material in spite of pockets of resistance because the long residual covers the long codling moth hatch. Recent research shows that some beneficials tolerate this material.

- **Chlorpyrifos –** 28 days PHI. Used for codling moth and leafrollers. This is the most reliable leafroller material. Applied from 1-5 times (avg. 2) per season to 42.3% of the apple acreage by ground at the median rate of 1.5 lb. a.i. per acre (4). Recent data indicate that azinphos-methyl resistant codling moth may exhibit negatively correlated cross-resistance with chlorpyrifos, making this a valuable material in managing organophosphate resistance in apples (5). It has a short residual and does not cover the entire egg hatch period. Chlorpyrifos also controls leafrollers, aphids, soft and armored scales if timed properly (6).

- **Esfenvalerate –** 21 day PHI. Applied postbloom to about 4% of the acreage by ground at 0.035 lb. a.i. per acre (4). This material is disruptive to the biological control of mites at higher rates and should only be used late in the growing season (6).

- **Permethrin –** Cannot be used after petal fall. Applied to >0.5 % of the apple acreage by ground at the rate of 0.19 lb. a.i. per acre (4). Extremely disruptive to biological control of mites and used little in the San Joaquin Valley because of this problem. Should only be used late in the season (6).

- **Phosmet –** 7 days PHI. Applied from 1 to 6 times per season (avg. 1) to 25.8% of the acreage at the an average rate of 2.5 lb. a.i. per acre (4). Less disruptive to beneficial mites and arthropods than some other organophosphates. Used in apple orchards where proximity to nonagricultural activity and native wildlife habitat necessitate use of a pesticide with minimal impact on non-target organisms.

- **Methyl-parathion –** PHI 30 days. Applied from 1-3 times (avg. 1) to 12.9% of the acreage at an average rate of 1.4 lb. a.i. per acre (4). Recent data indicate that azinphos-methyl resistant codling moth may exhibit negatively correlated cross-resistance with methyl-parathion, making this a valuable material in managing organophosphate resistance in apples (5). It is anticipated that this material will be applied to significant acreage in response to regulatory changes with azinphos-methyl and development of azinphos-methyl resistant codling moth, particularly in the southern San Joaquin Valley.

- **Diazinon** (see aphids) and **Methidathion** (see scale) will also control codling moth.

Leafrollers

Oblique-banded Leafroller, *Choristoneura rosaceana*

Orange Tortrix, *Argyrotaenia citrana*

Apple Pandemis, *Pandemis prysuana*

Fruittree Leafroller, *Archips argyrosphila*

Omnivorous Leafroller, *Platynota sultana*

Leafroller larvae roll leaves and web them together to form protective cases. However, leafrollers cause the greatest damage by feeding on fruit. Leafroller damage is typically shallow. They rarely penetrate the fruit deeply but feed on the surface, causing irregular, shallow scars resulting in commercially useless fruit. Leafrollers are usually controlled by treatments applied for codling moth. However, where codling moth mating disruption has been used, leafrollers have become major pests and are a barrier to adoption of codling moth mating disruption.

Obliquebanded leafroller is a pest throughout the state. Obliquebanded leafroller (OBLR) has two or possibly three generations each year. It overwinters on host trees mostly as third instar larvae within closely spun cocoons. As foliage emerges, larvae often tie terminal leaves together for shelter. Adults are tan with alternating light and dark brown bands across their forewings. Eggs are greenish yellow, flattened, and laid in overlapping masses. Larvae are green in color and often exceed 30 mm in length at maturity (2).

Orange tortrix and pandemis are major apple pests in coastal areas. Both species overwinter as larvae and there are 2 to 4 generations each year. Larvae feed on leaves, buds, and the fruit surface, causing severe damage as well as contamination by feces, and an entry point for rot organisms (2).

Fruittree leafroller is an early season pest and has a single generation per year. Larvae feed on blossoms, flower buds, and developing fruit. Badly damaged young fruit may fall but often remains on the tree, resulting in misshapen fruit that is culled at harvest.

Omnivorous leafroller is primarily a pest in the Central Valley, especially when apples are grown close to grapes and other hosts. Omnivorous leafroller feeding on fruit leave irregular, shallow scars on the surface similar to orange tortrix damage.

Monitoring: Pheromone traps are available for monitoring leafrollers but are of little practical value except to detect the presence of adult moths in the orchard and indicate when to expect second generation OBLR larvae. However, pheromone traps and a combination of degree days and fruit counts can be used to make treatment decisions for orange tortrix (2).

Controls

Biological:
Several parasitic wasps are important in regulating leafroller populations including *Hormius basalis*, a tachinid fly, *Nemorilla pyste*, *Macracentrus iridescens,* and *Pteromalus* spp. In addition, hemipterian predators, *Brochymena sulcatus,* and several *Phytocoris* spp. have been observed feeding on eggs and larvae (2).

Mating disruption looks promising for managing leafrollers. A combination leafroller–codling moth dispenser is being marketed by one company. At this time, control with leafroller mating disruption is variable and is not widely recommended.

Bacillus thuringiensis- 0 days PHI. Applied once or more to 11% of the acreage by ground at the rate of 0.75 lb. a.i. per acre. Treatments are usually applied in early spring during pink to full bloom while larvae are still actively feeding on leaves and before they construct nests.

Chemical:
Dormant and delayed dormant organophosphate treatments applied for San Jose scale and other pests generally control leafrollers in apples.

- **Chlorpyrifos** (See codling moth) applied during the delayed dormant period is the most effective leafroller material.

- **Carbaryl-** 3 days PHI. Used primarily in the coastal apple growing areas. Most effective material for orange tortrix. Applied by ground during the growing season to 21.8% of the acreage at an average rate of 1.5 lb. a.i. per acre. Also used as a fruit thinner if properly timed. Disruptive to the biological control of mites.

- **Spinosad –** Recent registration. Produced by soil organism, *Saccharopolyspora spinosa*. Also indications that this material may have activity against codling moth (7). No use data available.

- **Esfenvalorate** – (See Codling Moth)

Leafminers,
Phyllonorycter (=Lithocolletis) spp.

Leafminers are primarily an induced pest. They have become an increasing problem in apples on the West Coast as rates and frequency of broad spectrum insecticides for codling moth have increased. Early instar leafminer larvae are referred to as the sap-feeding stage. During this time, larvae are legless, flat, and white with a wedge shaped brown head. Their sucking mouthparts protrude forward to feed on the spongy mesophyll of leaves. As they feed, the outer layer of the leaf undersurface is separated from the tissue above. Later instars are known as tissue feeders. Larvae tie the sides of mines together with silk forming "tents." Leafminer damage is restricted to foliage and causes a reduction in photosynthesis. But it can indirectly affect fruit quality by retarding sugar development. This is most noticeable in red varieties because it results in poor color development (2).

Controls:

Biological:
Leafminer populations are usually kept at low levels by several species of parasitoid. Among the more important are *Pnigalio flavipes, Sympiesis marylandenis,* and *Sympiesis stigmata*. The occasional outbreaks of this insect in California occur probably as the result of chemical disruption of these parasitoids (2).

Chemical:

- **Oxamyl –** 14 days PHI. Applied postbloom by ground to 12% of the acreage at an average rate of 0.75 lb. a.i. per acre. Kill sap feeding larvae and eggs. Disruptive to the biological control of mites and other pests.

- **Abamectin** – 28 days PHI. No use data available for California.

Mites

Twospotted Mite, *Tetranychus urticae*

Pacific Mite, *Tetranychus pacificus*

McDaniel Mite, *Tetranychus mcdanieli*

European Red Mite, *Panonychus ulmi*

Brown Almond Mite, *Bryobia rubioculus*

Generally, moderate to high numbers of European red mites cause trees to look pale and leaves to turn bronze. However, high populations on Golden and Red Delicious can be damaging. Defoliation by European red and brown almond mite is not common in apples. In contrast, twospotted, McDaniel, and Pacific mites (webspinning mites) can cause almost complete defoliation that exposes trees and fruit to sunburn, reduces fruit size and sugar, and interferes with coloring of fruit and with harvest (2). Pacific mite is the dominant species in the San Joaquin Valley, two-spotted mite predominates in the Sacramento Valley and McDaniel mite is present in Sierra Foothill districts. However, over the years Pacific mite has become more common in the Sacramento Valley, possibly due to the use of propargite, which is more effective on two-spotted mite. Webspinning mites over-winter as adult females in the trees or on the orchard floor. All species are favored by hot, dry conditions, and as the weather becomes warmer, mites increase in numbers and move throughout the tree (2). Severe defoliation early in the season can reduce yield by 10% as well as interfere with production of sugars, size, and color (2). **Monitoring:** Mites can be monitored by leaf brushing or presence/absence sampling, (6).

Controls:

Biological Control:
Predators are important in regulating mite populations. The most dependable predator is the Western orchard predator mite, *Galandromus occidentalis,* which, if not disturbed with pesticides applied for other pests, can usually keep populations below damaging levels in well managed orchards. *G. occidentalis* is resistant to most organophosphates and insect growth regulators used for codling moth and leafrollers but is extremely susceptible to synthetic pyrethroids and carbamates (6). It should be noted that the predatory mites bred and released by Dr. Marjorie Hoy (formerly at UCB) were resistant to organophosphates, carbaryl, and sulfur. It is not known if most of the predators found today still retain those characteristics. Other important predators include sixspotted thrips, minute pirate bug, and a small beetle, the spider mite destroyer.

Cultural:
Minimize dust on orchard roads and maintain a well managed ground cover. Well irrigated, vigorous trees are less susceptible to mite damage (2).

Chemical:

- **Propargite -** 7 days PHI. Currently registered for use on non-bearing trees only. Applied post-bloom by ground to 18.1% of the acres at the rate of 2.1 lb. a.i. per acre (4). Propargite fits well in an IPM program and is the most effective material available. Does not disrupt biological control of mites.

- **Fenbutatin-oxide -** 14 days PHI. Applied post-bloom by ground to 7% of the acres at the rate of 0.6 lb. a.i. per acre (4). Does not disrupt biological control of mites and aphids. Fits well in an IPM program. Does not work well in cool weather.

- **Dicofol –** 7 days PHI. Applied by ground postbloom to 4.34% of the acreage at an average rate of 1.4 lb. a.i. per acre (4). Resistance to this material is widespread. Mite resurgence often follows the use of this material because it also kills predaceous mites.

- **Formetanate HCl** – 7 days PHI. Applied postbloom by ground to 3% of the acres at the rate of 0. l92 lb. a.i. per acre (4). Also harms predator mites.

- **Pyramite** – New material. Too early to determine effectiveness. No use data available.

- **Narrow Range Oils. -** 0 days PHI. Use data are not available. Oils can be applied post-bloom by ground at the rate of 4 gallons per acre (4). Oils are selective materials and effective acaricides when mite populations are low and predators are present. They must be used with caution because of potential phytotoxicity if trees are stressed or dry (6). Oils fit well in IPM programs if predator mites are present. Summer oils are occasionally used with mating disruption to help control codling moth in disrupted orchards. Oils may contribute to air pollution because of hydrocarbon volatilization and can cause fruit finish problems on some varieties.

Registered but no California use data available:

- **Clofentezine –** Do not apply after delayed dormant or delayed cluster. Does not control high mite populations. Does not disrupt biological control of mites. Fits well in an IPM program.

Scale Insects

San Jose Scale, *Quadraspidiotus perniciosus*

Italian Pear Scale, *Epidiaspis leperii*

European Fruit Lecanium, *Parthenocecanium corni*

San Jose scale is by far the most important scale insect found on apples. San Jose scale infests branches, shoots, leaves and fruit. The scales suck plant juices from the trees and inject a toxin. Fruit infested by San Jose scale is often bumpy; in extreme cases, fruit may be severely misshapen and stunted. Presence of the insect or a red halo caused by scales feeding on fruit results in culls from fresh market shipments. San Jose scale can seriously weaken branches and main scaffold limbs and kill fruiting spurs, thus causing permanent injury and even death to mature trees (2).

Italian pear scale usually feeds on scaffolds, thus reducing tree vigor. Italian pear scale is usually associated with moss and lichens and seems to be more common on stressed trees (2).

European fruit lecanium is seldom a pest of apples in California. The primary injury by European fruit lecanium is the production of honeydew that, in large amounts, can damage leaves and fruit. Sooty mold growing in the honeydew can cause blackened areas on leaves and fruit, causing markings that makes fruit unsuitable for fresh market (2).

Controls:

Cultural Control:
Proper irrigation and nutritional management minimize tree stress, help prevent Italian pear scale population increase, and allow trees to tolerate higher populations without damage. Reducing dust to minimize interference with natural enemies is also important (2).

Biological Control:
European fruit lecanium is frequently controlled by natural enemies, particularly *Metaphycus* spp. (2).

San Jose scale and Italian pear scale are heavily attacked by parasitic wasps *Aphytis* spp. and *Prospatella* spp. (2). In situations where broad spectrum insecticides have not been used, these parasites and predaceous beetles such as *Chilocorus orbus* and *Cybocephalus californicus* generally keep scale populations below damaging levels.

Chemical Control:
Many apple orchards are treated routinely during the dormant or delayed dormant seasons for scale and European red mites.

- **Methidathion** – Dormant or delayed dormant only. The most effective material for scale. It is applied by ground to 12.3 % of the acreage at an average rate of 1.49 lb.a.i. per acre (4). This material is toxic to beneficial insects and honey bees. Oil must be combined with this material in dormant sprays to control European red mite and brown almond mite eggs.

- **Diazinon –** 14 days PHI. Applied pre bloom by ground to 25.6% of the acres at the average rate of 1.5 lb. a.i. per acre (4). It is used extensively for ground applications mixed with petroleum oil during dormant period for control of San Jose scale, aphids and eggs of fruittree leafroller and mites. Diazinon can also be used in May, with or without oil for control of San Jose scale crawlers and aphids. It is effective against many lepidopterous pests if properly timed. San Jose scale resistance has been documented in San Joaquin Valley peach orchards but has not been documented in apples or in the Sacramento Valley. Diazinon is selective for predaceous mites but toxic to parasitic wasps and generalist predators.

- **Narrow Range Oils** – 1 day PHI. Applied dormant or postbloom by ground to 64% of the acres at the rate of 3.5 gallons per acre (4). Oils must be used with caution because of potential phytotoxicity if trees are stressed or dry (6). Oils are selective and will surpress mites. Oil will also suppress aphids and fruittree leafroller when applied during the dormant or delayed dormant seasons but followup treatments are often needed when populations are high (2). A drawback with oils is they may pollute air because of hydrocarbon volatilization.

- **Phosmet –** (See Codling Moth).

- **Chlorpyrifos –** (See Codling Moth).

- **Carbaryl –** (See Leafrollers) will also control the crawler stage.

Secondary Pests

White Apple Leafhopper, *Typhlocyba pomaria*

Rose Leafhopper, *Edwardsiana rosae*

Leafhopper adults of both species are white and about 1/8 inch long. Nymphs are also white in color, move rapidly sideways, and are usually found on the underside of leaves. Leafhoppers damage leaves by sucking on leaf tissue and removing green chloroplasts from cells, interfering with photosynthesis. Heavily infested leaves are speckled with white markings. In extreme cases leaves may be almost entirely whitened, and trees may defoliate prematurely producing small, poorly colored fruit. Leafhoppers do not feed on fruit but can cause blemishes on the fruit with excrement that appears as black specks. Honeydew and sooty mold produced by leafhoppers are hard to remove from fruit because they coalesce into sticky droplets around the calyx end of the fruit after rainfall or overhead sprinkling (2). Leafhoppers are seldom a problem in organic orchards and it is suspected they are induced by insecticide treatments for other pests.

Controls:

Biological:
Potentially parasitoids can be important in regulating leafhopper populations, but use of broad spectrum insecticides to control codling moth prevent them from being important population regulators.

Chemical:

Leafhoppers are relatively easily controlled if one of the following chemicals are applied:

- **Imidacloprid** – 7 days PHI. Applied by ground postbloom to 4.3% of the acreage at an average rate of 0.07 lb. a.i. per acre (4). Also shows activity on lygus and stink bugs.
- **Diazinon –** (See San Jose Scale)
- **Endosulfan** – (See Aphids)
- **Dimethoate** – (See Aphids)
- **Chlorpyrifos** – (See Codling Moth)
- **Oxamyl** – (See Leafminers)

Occasional Pests

Plant Bugs

Consperse Stink Bug, *Euschistus conspersus*

Lygus Bugs, *Lygus hesperus*and*Lygus elisus*

Lygus and stink bugs are most common in orchards with lush ground covers or in orchards surrounded by vegetation. Stink bugs occur in all California apple districts and are a chronic problem in many areas. Stink bugs generally overwinter beneath leaves and trash on the orchard floor or in protected places including box piles, brush, or ground cover near orchards. Stink bugs are stout, triangular shaped insects, about 3/8 inch long. Consperse stink bugs are generally brown or greenish in color and have piercing sucking mouthparts.

Like stink bugs, lygus bugs occur in all major apple districts and can cause severe damage, most often in orchards with permanent ground covers or in orchards located adjacent to crops or vegetation that hosts lygus bugs. Lygus bugs vary from green to brownish in color and are about ¼ inch long with piercing sucking mouthparts.

Both stink bugs and lygus bugs insert their mouthparts into fruit, causing dimples or irregularly depressed areas, or catfacing in mature fruit. The damage leads to culling at harvest. Internally, plant bug feeding produces white pithy areas that turn brown when the fruit is peeled, causing it to be discarded. Damage as high as 25% has been observed (15).

Controls:

Cultural:
Clean cultivation or destroying alternate hosts such as blackberries outside orchards will tend to reduce population pressure of both species. However, destruction of outside hosts is often impossible because of location or terrain.

Biological:
The role of predators and parasites has not been well investigated. However, predators such as bigeyed bugs, damsel bugs, and a parasitic wasp *Anaphes ovijentalus* are important in controlling lygus in cotton. Egg parasites for stink bugs have recently been imported from the Mediterranean region and Australia for southern green stink bug. There are indications this parasitoid may attack other stink bug eggs as well.

Chemical:
Often significant damage from true bugs may occur before populations are detected in orchards. Chemicals for true bugs in apples vary from area to area because tolerance and resistance is common.

- **Malathion** – 7 days PHI. Applied by ground postbloom to > 1% of the acreage at an average rate of 1.55 lb. a.i. per acre (4). Not effective for stink bugs.
- **Imidacloprid** – (See Leafhoppers).
- **Endosulfan** – (See Aphids).
- **Diazinon** – (See San Jose Scale).
- **Formetanate HCl** – (See Mites)
- **Dimethoate** – (See Aphids)

Rosy Apple Aphid,
Dysaphis plantaginea

Rosy apple aphid is a sporadic pest and potentially the most damaging aphid to apples because it injects a toxic saliva that can stunt fruit growth. When the aphids feed on leaves of fruit clusters, their saliva is translocated through the phloem to nearby fruit. Affected apples remain small, gradually puckering around the calyx end, and become badly misshapen and deformed. Damaged apples are discarded or culled at thinning or at harvest, thereby reducing yield (2).

Controls:

Cultural:
Prune out infestations in early spring. However, this is not an option in most orchards.

Biological:
A number of wasp parasites and predators such as ladybird beetles and green lacewings help regulate rosy apple aphid populations. However, in many cases, control by natural enemies is too late to prevent economic damage.

Chemical:
Properly applied delayed dormant application of oil plus a suitable organophosphate is basic to controlling rosy apple aphid in most commercial apple orchards (2). This treatment helps prevent early season injury by the aphid and should eliminate the need for more sprays.

- **Diazinon –** (See San Jose Scale)

- **Endosulfan –** 21 days PHI. A very effective aphid material. Applied by ground postbloom to 2.5% percent of the acreage at an average rate of 1.00 lb. a.i. per acre (4). A selective material that fits well in an IPM program. This material cannot be used near waterways because it is extremely toxic to fish.

- **Dimethoate –** 28 days PHI. A systemic material effective on aphids, leafhoppers, and other hemipterous pests. Applied postbloom by ground to 3.3% of the acreage at an average rate of 0.38 lb. a.i. per acre. Disruptive to the biological control of mites.

- **Chlorpyrifos –** (See Codling Moth).

- **Imidacloprid** – (See Leafhoppers)

Minor or Occasional Pests

Rust Mites, *Aculus schlechterdali* and *Calepitumerus baileyi*

Rust mites which occur in all but the coastal apple districts, rarely cause damage. Rust mites are so small you need a hand lens to detect them. They are wedge-shaped with the larger end at the head. In apple orchards, the presence of apple rust mites generally is advantageous, and treatment is rarely recommended even when high populations of 200 or more mites per leaf turn leaves silver. Apple rust mites provide an alternate food source for predatory mites when other mites are not plentiful (2).

Controls:

Cultural:
Potential mite problems can be reduced by controlling dusty conditions, managing the ground cover, and keeping trees adequately irrigated. Avoiding the use of disruptive materials such as synthetic pyrethroids is also important.

Biological:
The mite predators mentioned previously under "mites" play an important role in regulating rust mite populations in apple orchards.

Chemical:
All chemicals listed under mites will also control apple rust mite if populations are extreme.

- **Carbaryl** (See leafrollers)
- **Endosulfan-** (See Aphids).
- **Diazinon-** (See Aphids).
- **Sulfur** – (See Apple Scab)

Woolly Apple Aphid,
Eriosoma lanigerum

Woolly apple aphid is found throughout California apple growing regions but is a major pest in coastal counties. Woolly apple aphids infest roots, trunks, limbs, and shoots, producing galls at the site of infestation. On some varieties such as Yellow Newtown, woolly apple aphids enter the calyx of the apple if heavy populations are present. Heavy infestations of the aphids on roots can retard tree growth or stunt and kill young trees. Aerial colonies may form at the axils of leaves causing cankers and lack of fruit bud development. When aerial populations are high, honeydew and growth of sooty mold can also be a problem (2).

Controls:

Cultural:
Where woolly apple aphid is a serious problem, reportedly resistant stocks as M111 or M106 may be used (2).

Biological:
The parasite *Aphelinus mali* can completely control aerial colonies. In addition, such predators as lacewings, lady beetles, and syrphid fly larvae are active throughout the season and can have a positive impact on reducing colonies in the absence of broad spectrum insecticides (2).

Chemical:
Aerial colonies can be controlled by chemicals, but root colonies are unaffected or at best difficult to control.

- **Diazinon –** (See San Jose Scale)
- **Endosulfan –** (See Rosy Apple Aphid)
- **Dimethoate –** (See Rosy Apple Aphid)

Green Apple Aphid,
Aphis pomi

Although green apple aphid is subject to wide fluctuations in abundance, it generally occurs yearly in most apple orchards. The most serious damage occurs when heavy populations feed on young nonbearing trees, stunting tree growth, and stimulating lateral branch growth. On mature trees, losses are due primarily to the honeydew dripping onto foliage and fruit, which causes culled fruit due to blemishes.

Controls:

Biological:
Predators such as lady beetles, green and brown lacewings, and syrphid fly larvae generally control green apple aphid populations before serious damage occurs.

Chemical:
Green apple aphid is easily controlled with one of the materials listed under rosy and woolly apple aphids.

- **Imidacloprid –** (See Leafhoppers)

Redhumped Caterpillar,
Schizura concinna

Larvae of redhumped caterpillar are yellow with longitudinal reddish and white stripes. The head and fourth abdominal segment are red. They pass the winter as pupae in the soil and there are three generations per year. Larvae feed on leaves. Heavy populations can cause severe defoliation resulting in sunburned fruit and small fruit size caused by photosynthetic reduction (2). The caterpillars are most damaging to young trees, but can cause 5% yield loss if left uncontrolled.

Controls:

Biological:
Two parasitic wasps, *Hypersoter* sp. and *Apanteles conglomerates*, are important in regulating redhumped caterpillar populations. Generalist predators such as spiders, lacewings, bigeyed bugs, and damsel bugs also prey on larvae (2).

Chemical:
This pest is easily controlled by ground or air applications.

- *Bacillus thuringiensis* – (See Leafrollers)

- **Diazinon –** (See San Jose Scale)

- **Phosmet, Azinphosmethyl,** and **Chlorpyrifos** (see codling moth) will also control this pest.

Green Fruitworms:
Orthosia hibisci, Amphipyra pyrqmisoides, Xylomyges curialis

Green fruitworms include several species of caterpillars, all of which are generally pale green or dull brown. They are well distributed throughout the state and there are regional differences in populations of the different species. They are not a major problem in apples that have received a dormant organophosphate treatment. All of the above species have but one generation per year. They cause similar damage by feeding on young leaves and fruit early in the season, causing the fruit to be misshapen and scarred (2).

Control:

Biological:
A number of parasitic wasps attack green fruitworms. Generalist predators such as *Orius spp.*, green lacewings, and plant feeding bugs probably feed on larvae. However, little is known about the impact they have on populations.

Chemical:

- *Bacillus thuringiensis* – (See Leafrollers)
- **Diazinon –** (See San Jose Scale)
- **Phosmet, Azinphosmethyl,** and **Chlorpyrifos** (see codling moth) will also control this pest.

<u>Fall Webworm,</u>

Hyphantria cunea

Larvae of the fall webworm feed inside silken tents, skeletonizing leaves, reducing photosynthesis, and exposing nuts to sunburn. The larvae are pale brown or gray with long hairs covering the body. Fall webworms overwinter as pupae and emerge in late summer. There is one generation per year. Infestations are localized and usually controlled by insecticides applied for other pests (2). Heavy populations can almost completely defoliate trees and could cause 20% yield reduction on 5% of the acreage. **Monitoring:** Webworms are monitored for their presence by looking for silken tents.

Controls:

Chemical:
Fall webworm is usually controlled by insecticides applied for other pests. Tents must be wetted thoroughly for insecticide to penetrate.

- **Diazinon –** (See San Jose Scale).
- *Bacillus thuringiensis* - (See Leafrollers).
- **Phosmet, azinphos-methyl, diazinon** and **chlorpyrifos** (see codling moth) will also control this pest.

Infrequent Pests

Leaffooted Bug,
Leptoglosssus clypealis

The leaffooted bug is an infrequent pest in apples but can cause severe damage in certain areas. Adults are about 20 mm long, yellowish brown, and have a yellow band across the middle of its back. The back is flat, and the hind legs have characteristic leaf-like enlargements. The leaffooted bug overwinters near orchards, often in conifers such as juniper, and arborvitae, and around prop piles or other protected areas. It feeds on fruits causing catfaced or misshapen fruit that are culled at harvest (2). Damage is spotty but 5% damage can result in heavily infested areas.

Woodboring Beetles

Shothole Borer, *Scolytus rugulosus*

Branch and Twig Borer, *Polycaon confertus*

Pacific Flatheaded Borer, *Chrysobothris mali*

Woodboring beetles generally limit their attacks in apples to sunburned, unhealthy trees and can be managed by encouraging healthy trees through proper nutrition and irrigation practices. However, Pacific flatheaded borer can be a serious problem in newly planted orchards by girdling and causing death of planted trees. It is not uncommon for 25% of a young orchards to be killed unless preventive measures are taken.

Controls:

Cultural:
Flatheaded borer in newly planted trees can be prevented by properly painting the trunk with white latex paint or using trunk wraps to prevent sunburn (6). Insecticide is not needed in the paint.

Shothole beetles are managed by keeping trees healthy and removing and destroying infested trees.

Western Flower Thrips,
Frankliniella occidentalis

On occasion western flower thrips appear on apple trees early in the bloom period and deposit eggs in young fruit before petal fall. The egg laying site develops into a blemish known as pansy spot. Green varieties usually experience greater numbers of these blemishes than red varieties, probably because the damage is more noticeable on green varieties.

Controls:

Cultural:
The orchard floor should not be disturbed during bloom.

Chemical:

- **Methomyl** – 14 days PHI. Applied to >1% of the acreage at a rate of 0.75 lb. a.i. per acre (4). Will cause disruption of biological control of mites.

- **Formetanate HCl –** (See Mites)

Diseases

Various pathogenic microorganisms can cause disease in apples. The severity of their damage depends on the virulence of the pathogen, the tree variety, and the vigor and maturity of the tree (2).

Diseases of Twigs, Leaves, Blossoms and Fruit

Apple Scab,
Venturia inaequalis

Scab, considered the most serious disease of apples in California, is most severe in coastal areas, where spring and summer weather is cool and moist. However, scab can cause serious damage in other apple growing districts when wet spring weather occurs. Apple scab affects flowers, fruit, and foliage, causing severe losses in yield and fruit quality. Scab lesions usually are seen first in spring on expanding leaves. Lesions tend to be circular with distinct margins and have a black scabby appearance. Severely affected leaves may turn yellow and drop prematurely. Scab may infect flower buds and fruit before, during, and after bloom through summer. Fruit infections after petal fall begin as dark green spots that eventually turn black. The center of the infected area becomes dry, cracked, and scabby looking. As fruit develops, it becomes misshapen; severely affected young fruit may drop causing a loss in yield. Fruit that stays on the trees are culled at harvest (2). Damage can exceed 50% in severe scab years without treatments.

Controls:

Cultural:
Fall foliar applications of urea reduce primary spores the following spring by helping to speed decay of infected leaves on the ground.

Chemical:

- **Fenarimol** – 30 days PHI. Excellent for scab (10). Applied by ground or air either pre- or post-bloom to 40% of the acres at the rate of 0.075 lb. a.i. per acre (4). Has both protectant and kickback properties. Also excellent for mildew.

- **Myclobutanil** – 14 days PHI. Provides good to excellent control of scab (10). Applied pre- or post-bloom to 55.4 % of the acres at an average rate of 0.10 lb. a.i. per acre (4). Has both protectant and kickback properties. Also excellent for mildew.

- **Triflumizole** – 14 days PHI. Provides good to excellent control of scab (10). Applied pre- or post-bloom to 2% of the acres at an average rate of 0.38 lb. a.i. per acre (4). Has both protectant and kickback properties. Also excellent for mildew.

- **Captan –** 1 day PHI. Fair for scab control (10). Applied pre- or post-bloom to 17% of the acreage at an average rate of 2.93 lb. a.i. per acre (4). Acts as a protectant only. Valuable material for resistance management programs.

- **Benomyl** – 14 days PHI. Rated good for scab control (10). Applied pre- or post-bloom to 5.4% of the acres at an average rate of 0.38 lb. a.i. per acre (4). Has both protectant and kickback properties. Also provides good control of mildew.

- **Thiophanate Methyl** - 14 days PHI. Applied pre- or post-bloom to 13.2% of the acreage at an average rate of 0.70 lb. a.i. per acre (4). Has both protectant and kickback properties. Provides good control of mildew.

- **Thiram –** 1 day PHI. Applied to 4.9% of the acres at an average rate of 1.63 lb. a.i. per acre (4). Acts as a protectant only. Valuable material for resistance management programs.

- **Mancozeb** – 77 days PHI. Applied pre-bloom to 24.3% of the acreage at an average rate of 2.25 lb. a.i. per acre (4). Acts as a protectant only. Valuable material for resistance management programs.

- **Maneb -** 77 days PHI. Applied to 3% of the acreage at an average rate of 2.0 lb. a.i. per acre (4). Acts as a protectant only. Valuable material for resistance management programs.

- **Ziram** – 14 days PHI. Applied pre- or post-bloom to 24% of the acreage at an average rate of 5.6 lb. a.i. per acre (4). Acts as a protectant only. Valuable material for resistance management programs.

- **Cyprodinil** – 72 days PHI. No use data available.

Powdery Mildew,
Podosphaera leucotricha

Powdery mildew occurs to some extent in all apple-growing areas. Apple varieties vary greatly in susceptibility to powdery mildew. In spring, white fungal mycelium develops over petals, sepals, and flower stems of infected blossoms. Infected blossoms fail to set fruit. On leaves, whitish patches appear along leaf margins, usually on the underside of leaves. These white areas later spread over the entire leaf and then over the entire shoot. Shoots infected with mildew are stunted and sometimes killed. Severely infected leaves drop. Fruit infection usually occurs only on young fruit. Infected fruits are stunted and develop a netlike russetting on the surface. Powdery mildew results in an overall reduction in quantity and quality of yield. Severely infected trees can suffer considerable damage in the range of 25-50%.

Controls:

Cultural:
Pruning out infected shoots during dormancy will help reduce the inoculum load the following spring. However, it is difficult to remove all infected shoots and fungicides are generally needed on susceptible varieties.

Chemical:
Scab spray programs also control powdery mildew if fungicides effective against both fungi are used.

- **Sprayable Sulfur –** 1 day PHI. Good for mildew control (10). Moderately effective for scab control. Applied to 25% of the acres at an average rate of 6.5 lb. a.i. per acre (4).

- **Lime Sulfur –** 1 day PHI. Good for mildew control (10). Moderately effective for scab control. Applied to 11% of the acreage at an average rate of 14.7 lb. a.i. per acre (4). Acts as a protectant only. Provides good control of mildew.

- **Triadimefon** – 45 days PHI. Excellent for powdery mildew (10). Applied by ground pre and post bloom to >1% of the acreage at an average rate of 0.1 lb. a.i. per acre (4). Good for apple scab.

Materials listed below are rated good to excellent for powdery mildew control (10):

- **Fenarimol** – (See Apple Scab).
- **Myclobutanil** – (See Apple Scab).
- **Triflumizole** – (See Apple Scab).
- **Benomyl** – (See Apple Scab).
- **Thiophanate Methyl -** (See Apple Scab).
- **Cyprodinil** – (See Apple Scab)

Fire Blight,
Erwinia amylovora

Although not as susceptible as pear, fireblight can be a serious disease on some apple varieties. Fireblight development is influenced primarily by seasonal weather. Warm weather, accompanied by rain and hail is ideal for disease development. The climate in most apple growing areas and especially in the Central Valley is conducive to disease development. Fireblight causes blossom clusters to wilt and collapse in late spring. Young tender shoots can also be infected. Blight infections kill fruiting spurs, and it may move into twigs and branches from infected clusters. In some varieties major branches may be killed as cankers expand and girdle limbs. In highly susceptible varieties entire young trees may be lost. Blight injury can reduce yields of highly susceptible varieties up to 25%.

Controls:

Cultural:
Avoid irrigation, especially overhead irrigation, when favorable infection temperatures and blossoms are present.

Avoid excessive shoot growth by carefully managing nitrogen applications.

Prune out holdover cankers during the dormant period. Shears should be disinfected after each cut.

Prunings should be removed from the orchard and burned.

Biological:
Pseudomonas florescens – 0 days PHI. Recently registered biological control material. No use data available.

Chemical:

- **Streptomycin** – 50 days PHI. Use reports indicate this material was used an average of 1.5 times for 100% of the acreage at the average rate of 0.13 lb. a.i. per acre (4). However, these figures are misleading since many acres were not treated and others received multiple treatments during the critical bloom period. Streptomycin-resistant strains of fire blight bacteria are present in some districts (6).

- **Fixed copper –** Use until ½ inch green stage. Applied to 27% of the acreage at an average rate of 2.6 lb. a.i. per acre (4). This material may cause severe russetting to some varieties including Granny Smith (6).

- **Metalaxyl** – Recently registered material. No use data available.

Root and Crown Diseases

Phytophthora Root and Crown Rot,
Phytophthora spp.

Phytophthora root and crown rot are serious diseases of apples in the Central Valley and Coastal districts. About 11 species of *Phytophthora* attack apple and cause either slow or rapid tree decline. The speed with which the tree declines is determined by the species involved, the age of the tree, the rootstock, water management, and climate conditions (2).

Root Rot: Certain *Phytophthora* spp. primarily cause feeder and secondary roots to decay and result in slow decline of the tree. Others however, cause massive infection and decay of the entire root system; rapid decline and death of the tree follow (2). The bark and outer wood of infected roots are reddish to dark brown in color.

Crown Rot: Trees with *Phytophthora* crown rot infection usually decline rapidly. Organisms invade the area of the trunk at or directly below grown level where the fungus decays the bark and cambium, often girdling the tree. The bark of dead or dying trees is brown and dead at and below ground level (2).

Controls:

Cultural:
Proper water management is the key to controlling root and crown rot. Good drainage is a must, especially in areas that flood frequently. Avoid planting in heavy clay soils.

Keeping the trunk area free from debris or heavy weed growth will help alleviate problems with crown and root rot.

Some rootstocks are resistant or tolerant to crown and root. M106 , M7a, and M111 are most successful in crown and root rot susceptible areas in different districts around the state (2). Rootstock resistance may depend on the *Phytophthora spp.* Present in the particular orchard in which they are used.

Chemical:

- **Metalaxyl** – Applied in spring as a soil drench before growth begins. Applied to >0.5% at an average rate of 0.7 lb. a.i. per acre (4). Treatment limited to drip line. Can also be applied foliar for fireblight.

Armillaria Root Rot or **Oak Root Fungus,**
Armillaria mellea

The severity of this fungal disease depends on the rootstock and the strain of *A. mellea*. Many strains of the fungus exist, ranging from nonvirulent or weakly virulent to extremely virulent that kill trees shortly after infection occurs. The pathogen invades the roots, crown, and basal trunk; eventually girdling the crown region, destroying the entire root system and causing death of the tree. The organism can survive for many years in dead roots of many different species of trees (2).

Controls:

Management of *Armillaria* root rot primarily depends on the use of pre-plant soil fumigation, root stock selection and the selection of noninfested sites for planting (2).

Cultural:
One of the best methods of managing *A. mellae* is careful selection of orchard sites before planting an orchard. Avoid planting where forest or oak woodland have been cleared recently or on a site with a history of *Armillaria* root rot.

Chemical:
Methyl bromide has shown some promise for control of *A. mellea* at the rate of 300-600 lb. per acre

applied by injection with tarping. It is recommended that a deep-rooted covercrop be grown on the soil to dry it out completely before treating for *A. mellae*. Even under these conditions, eradication is difficult. Methyl bromide also reduces *Phytophthora*, verticillium wilt, and other soil inhabiting organisms. (See Nematodes)

<u>Crown Gall,</u>
Agrobacterium tumefaciens

Although crown gall can affect established orchards, the disease is most damaging to young trees. If left unchecked, crown gall may progress around the crown, weakening and eventually girdling the tree. Young galls are smooth; as they age, they become rough and increase in size. Old galls are dark, brittle, and cracked. The pathogen usually enters through wounds; young trees in nurseries are particularly prone to infection because of the many potential injuries during rearing, digging, and handling (2).

Controls:

Biological:
Agrobacterium radiobacter – Roots are dipped in a protective solution of this material before planting. No record of use on apples in 1995. Strains of *A. tumefaciens* resistant to *A. radiobacter* have been reported in other crops (14).

Chemical:
The primary technique for managing this disease is using clean nursery stock. This is accomplished at present by fumigating with methyl bromide and using biological control agents prior to planting. Both are widely practiced already in California.

Trunk and Branch Diseases

<u>European Canker,</u>
Nectria galligena

European canker is associated with high rainfall and occurs primarily on apples grown in North Coast areas. Varieties vary in susceptibility to this disease. Primary infections occur through leaf scars and wounds after the first fall rains. Lesions develop the following spring and enlarge into a canker, and concentric ridges develop around the elliptical sunken areas of dead tissue. The main effect of European canker is the destruction of fruit wood, which can significantly reduce crop yield.

Controls:

Cultural:
Prune out and burn diseased wood in early summer. This reduces the inoculum for new infection.

10:10:100 Bordeaux or fixed copper applied during fall before rains begin will control this disease.

Nematodes

Lesion Nematode, *Pratylenchus vulnus*and *Pratylenchus penetrans*

Dagger Nematode, *Xiphinema americanum*

Root Knot Nematode, *Meloidogyne* spp.

Plant parasitic nematodes are microscopic roundworms that feed on plant roots of most plants, including apples. They live in soil or within the cortical tissues of the roots. The extent of the damage caused by nematodes in apples depends largely on the density of the nematode population, soil conditions, and rootstock selection. Nematode-infested trees have a poorly developed, inefficient root system and frequently exhibit deficiencies in nitrogen, water, and other nutrients. Nematode feeding is often associated with reduced fruit size. In situations where tree growth has been visibly impaired by the second year, the affected trees may never overcome the nematode problem. Symptoms of nematode infestation include lack of vigor, small leaves, twig dieback and a sparse root system, particularly the lack of small feeder roots. Root galls are an indication of root knot nematode.

Dagger nematodes do not enter tree roots but their long stylet mouthparts allow them to feed deep inside root tissues. Dagger nematodes are most common in northern California soils. They also occur frequently in other production areas but damage by this nematode in apple orchards in California has not been quantified. However, there is cause for concern because the nematodes generally occur at higher population levels than that found on most other crops. Dagger nematodes vector the tomato ringspot virus, a disease causing apple union necrosis and decline, especially on the combination of Red Delicious on M106 rootstock (6).

Root lesion nematodes damage roots by moving through cortical tissues and feeding in these areas. Root lesion nematodes can girdle and effectively prune roots while feeding. Small feeder roots are particularly susceptible to damage. With first-leaf trees, damage due to replant problems and the lesion nematode can be severe. Stunted trees occur within irregular, circular-shaped areas across the orchard. Among older plantings, damage is barely discernible. Fruit size and quantity are reduced with only slight apparent stunting in overall tree growth. They are occasionally associated with the apple replant disease, which is characterized by poor growth of young trees after transplanting.

Root knot nematodes take up a single feeding site within conductive tissue inside a root where they remain for their entire life. As they feed, the host root produces a gall or swelling around the enlarging nematodes causing small galls on roots. Some legumes grown for cover crop on the orchard floor provide an excellent habitat and food source for root knot nematode. Unfortunately many cover crops, including clovers do not show obvious symptoms of root galling (6).

Viruses are not a problem with certified virus-free rootstocks. If nurseries ever begin producing stock from nematode infested sites because a suitable fumigant is unavailable, viruses could become a significant problem.

Controls:

Cultural:
Management of nematodes starts before planting an apple orchard. Soil samples should be taken to identify the nematode species present to determine a course of action (2).

Continued fallowing for at least 4 years or use of non-host crop rotation can significantly reduce nematode populations before planting. However, this is usually not an economically feasible option (2).

To prevent the introduction of nematodes in an orchard, certified nematode free planting stock is used.

Most standard rootstocks and some dwarfing rootstocks are believed to have some tolerance to *P. penetrans*, the root lesion nematode species that is frequently found in apple orchard soils in northern California. However, the dwarfing rootstocks are considered to be susceptible to *P. vulnus*, which is common in the orchard soils of the San Joaquin Valley.

Biological:
There are no known biological agents that are deliverable to soil or the surfaces of roots that will provide relief from nematodes.

Chemical:

Post-plant Treatments

- Fenamiphos is the only post-plant nematicide registered in California for bearing apples. It is partially effective only against ectoparasitic nematodes.

Pre-plant Treatments

Pre-plant fumigation is common in replant situations. Nematode numbers are greatly reduced for as long as 6 years by fallowing 1 or 2 years and then fumigating prior to replanting. Methyl bromide fumigation serves the important function of killing all the remaining roots within the surface 5 feet of soil profile. Other fumigants may not. Without fumigation these roots remain alive two years after the old trees have been removed and the soil deep-ripped. Few growers could afford to idle their land for the 4 to 5 years necessary to achieve adequate relief from the replant problem plus root lesion nematode (9).

- **Methyl bromide** is used as a pre-plant treatment when replanting into soils previously in orchard crops. Applied to a total of 123 acres at an average rate of 97 lb. a.i. per acre (4). The low rate indicates most of this material was used in treating individual tree sites prior to replanting in an existing orchard, or individual sites in a new orchard or strip treatments. It is applied one to two feet deep, usually with a plastic tarpaulin stretched over the field surface. In order to save on costs, growers in some regions may treat only the planting strips or the individual planting sites at approximately 100 lb. per acre, with or without use of a tarp. There are no effective post-plant nematicides and no rootstocks are known to be resistant to root lesion nematode, so growers make a critical decision whenever they decide on a partial fumigation or to not fumigate at all. The damage by nematodes is severe enough on apples that without methyl bromide or an effective alternative, the resulting orchards will be weaker with fewer roots and any damage with above ground pests will be increased. Fumigation is common in replant situations in the San Joaquin Valley. Additionally, availability of an effective pre-plant material has greatly reduced the need for annual post-plant treatments.

- **1,3-Dichloropropene** is the closest replacement for methyl bromide, but its use for this purpose in California was suspended from 1990 to 1996. Today there are serious acreage restrictions and a limitation of 350 lb. per acre associated with its use. Use data are not available at this time. Excessive volatilization has been the key shortcoming to its recent use and the tree fruit industry has been searching for improved methods of application to limit in-field volatilization without jeopardizing efficacy. Before 1990, the normal treatment rates for 1,3-dichloropropene were up to 800 lb. per acre. Newer methods of killing roots plus the lowered rates of 1,3-dichloropropene and the use of a water seal containing metam-sodium biocide will soon receive field evaluation as a methyl bromide alternative. It is premature to predict the results in commercial settings (9).

- **Metam-sodium** – Applied at individual tree sites pre-plant to <0.01% of the acreage at an average rate of 60 lb. a.i. per acre (4). This material is difficult to move deep enough into the soil to be of much use (9).

- **Fenamiphos** – For non-bearing trees only. Applied to soil to just under 1% of the acreage at an average rate of 0.96 lb. a.i. per acre. Efficacy is variable (4).

- **Sodium tetrathiocarbonate** –received a registration on prunes in California in the spring of 1997. It contains the active ingredient sodium tetrathiocarbonate which releases carbon disulfide when in contact with soil. Several small scale field trials have shown that flood applications of Enzone can reduce ring nematode population on prunes plus reduce the incidence of bacterial canker. Neither the nematode nor disease are significant in apples but as research continues it may offer some promise for managing other nematodes important in apples.

Weeds

Weeds can cause a multitude of problems in apple orchards by reducing the growth of young trees as they compete for water, nutrients, and space. Weedy orchards have higher humidity and slower drying conditions than weed-free orchards, creating an environment ideal for development of such diseases as scab and crown rot. Weeds also contribute to vertebrate and invertebrate pest problems. Gophers, rabbits, and meadow mice are more common in weedy orchards and do more damage than in weed-free ones because weeds shelter rabbits and mice while they feed on tree bark. Because dense weed stands lower orchard temperatures, the risk of frost damage is greatly increased in spring. However, in summer, cooler temperatures in weedy orchards are desirable to reduce the incidence of sunburn on fruit. Many training systems do not allow for cross cultivation and most orchards are no-till, requiring the use of herbicides and/or mowing to control weeds.

The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, microsprinkler, and sprinkler-irrigated orchards. Pre-emergent herbicides are generally used only in the tree row. This reduces the total amount of herbicide and prevents the surface roots in the tree row from being damaged by cultivation equipment. By treating the tree row only, 25% to 33% of the total acreage is treated. Middles between tree rows are usually mowed. Soil characteristics have an effect on the weed spectrum (often 15–30 species per orchard), the number of cultivations and irrigations required, and the residual activity of herbicides. Irrigation methods and the amount of irrigation or rainfall affects herbicide selection and the residual control achieved.

Apple orchards may benefit from plants on the orchard floor if they are carefully managed. These plants in a well-maintained ground cover, can help increase water infiltration, reduce soil compaction, maintain soil organic matter content, cool the orchard, and provide habitat for beneficial insects (2).

Monitoring: Treatment decisions and herbicide selections are based on dormant and early summer weed surveys.

Controls:

Cultural:

Cultivation is the predominant method of weed control in non-irrigated orchards, primarily to conserve soil moisture during the summer. It is also more practical for managing the orchard floor if contours and checks are used for flood irrigation. Tilling the ground cover under in spring and smoothing the bare soil provides a slightly warmer environment to protect against frost.

In nontilled orchards, weeds are mowed in tree row middles and herbicide treatments are used down the tree row. Mechanical mowing offers several advantage over tilling. It is faster and has lower power demands than discing or rototilling. It uses light equipment that is less expensive and easier to operate than cultivating and it allows access to the orchard during wet periods. An additional advantage of mowing is it allows tree roots to grow closer to the surface to make use of water and nutrients in the topsoil. A ground cover reduces dust which can minimize mite and scale problems (2).

Mulching down the tree row helps control weeds and depending on the mulch, can aid water conservation, regulate soil temperature, and prevent erosion. The cost of labor and materials make mulching of weeds prohibitive in all but very small orchards. However, a new technique known as "mow and blow" may make mulching more affordable. A drawback of mulching is that it may attract mice, moles, and gophers.

Grazing is rarely an option because of problems associated with managing animals and potential tree damage.

Hand hoeing down the tree row is an option but rarely used because of excessive labor costs.

Chemical:

- **Glyphosate -** 14 days PHI. Most often used herbicide (4). Applied during the dormant, pre- and/ or post-bloom by ground. Often applied at low rates several times during the season. Applied to 59% of the apple acreage. Annual use rate averages 0.86 lb. a.i. per acre (4). Nonselective systemic used for a broad range of weed species. Effective anytime on emerged, irrigated, rapidly growing, non-stressed weeds, but activity is slower at lower temperatures. Best material available for most perennial weeds. Cannot eradicate field bindweed or nutsedge. Not effective on some broadleaf weeds at older stages of growth (malva and filaree). Continued use of this material leads to a shift of species and selection of tolerant species (6). Light activated spray technology has reduced the amount of material applied when weed cover is low by 50 to 80% (8).

- **Oxyfluorfen -** Apply following harvest up to February 15. Applied by ground one time per season on 18% of acreage at an average rate of 0.8 lb. a.i. per acre (1). Selective broadleaf herbicide effective as a pre- and post-emergent material. Particularly useful when combined with glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with glyphosate. Oxyfluorfen is the only effective material for malva (8).

- **Simazine –** Applied during fall or pre bloom. Applied to bare soil or in combination with glyphosate by ground one time per season on 11.5% of the acreage at an average rate of 0.90 lb. a. i. per acre (4). Pre-emergence herbicide of most annual grasses and many broadleaf weeds. Effective when combined with translocated herbicide such as glyphosate or the contact herbicide paraquat, and a broadleaf pre-emergence herbicide as oxyfluorfen. Typically used for down the row treatment to maintain clean row for irrigation emitters and season long weed suppression (6). Simazine is the only material effective on fleabane and horseweed, but controls grasses poorly (8).

- **Paraquat -** 0 days PHI. Applied by ground one or more times per season to 37% of the acreage at an average rate of 0.73 lb. a.i. per acre (4). Nonselective post-emergence material used for quick burn-down of most weed species. Less effective against perennials that will re-grow with vigor (e.g., bermudagrass, dallisgrass, johnsongrass, and bindweed) (8). Most effective when used on early spring or winter growth of annual grass species in combination with pre-emergence herbicides.

- **2-4-D -** 14 days PHI. Applied as a directed spray post-bloom by ground one or two times to 3% of the acreage at the average rate of 0.18 lb. a.i. per acre (4). Post-emergence systemic herbicide selective for most broadleaf annual weeds. Provides partial control of field bindweed. Useful for controlling troublesome perennials (8).

- **Oryzalin -** 0 days PHI. Applied at 2-4 lb. as pre-emergence in the tree strip by ground one time per season on 10% of the acreage at the average per acre rate of 2.0 lb. a.i. per season (4). Pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals. Very safe for young or newly planted trees and on sandy or sandy loam soils (8). It is used to maintain control in strips down the row. Often used in combination with other pre-emergence herbicides.

- **Norflurazon -** 60 days PHI. Applied pre-bloom by ground one time per season on 8.5% of the acreage at the rate of 1.46 lb. a.i. per acre (4). Pre-emergence selective herbicide similar to oryzalin, but is effective on more annual broadleaf and grass species. Can suppress yellow nutsedge or bermudagrass when used year after year (8). Can cause minor damage to younger trees or those planted on sandy or sandy loam soils. Usually used on new plantings. Primarily a grass control material (8).

- **Napropamide -** 0 days PHI. Applied pre-bloom one time per season on 2.2% of the acreage at the rate of 1.68 lb. a.i. per season in the tree row (4). Pre-emergence herbicide effective on annual grasses and several annual broadleaves (8). Must be applied and incorporated with irrigation or rain within seven days. Effectively maintains weed free strips down the row. May be applied in late winter with glyphosate for late burn down. Used on bearing and non-bearing trees.

- **Diuron –** Apply in spring before budbreak. Applied to 2.4% of the acreage at an average rate of 1.16 lb. a.i. per acre (4). Pre-emergence herbicide effective on annual grasses and several annual broadleaf plants. Does not control spurge or bristly oxtongue.

- **Pendimethalin -** Non-bearing trees only. Applied pre-emergence by ground one time per season to >1% of the acreage at the rate of 1.37 lb. a.i. per acre. Effective on annual grasses and some broadleaf weeds (8).

Vertebrate Pests

The most damaging vertebrate pests in apple orchards are pocket gophers and meadow mice. On occasion, deer, jackrabbits, porcupines, ground squirrels, and birds cause problems.

Pocket gophers feed on the tree's bark in the crown or root region and can girdle and kill young trees or reduce the vigor of older ones. Meadow mice also feed on the tree bark, usually at or just below the soil line and occasionally girdle trees, especially young ones. Jackrabbits feed on the bark of young trees; deer and porcupines feed on young foliage from trees of any age. Ground squirrels are a nuisance primarily because their burrows can be disruptive. The most damaging birds in apple orchards are house finches, which feed on buds, young fruit, and mature fruit, and scrub jays that peck holes in fruit as it nears maturity (2). Management of vertebrates is sometimes difficult because of local, state, and federal regulations concerning birds and wildlife.

Pocket Gophers,
Thomomys spp.

Pocket gophers are stout-bodied, short-legged rodents 6 to 8 inches long. Pocket gophers are common in areas of abundant plant growth. They feed primarily on succulent underground parts of herbaceous plants. They live almost entirely underground. They create extensive burrows for living and feeding.

Pocket gophers frequently live in orchards. They are active throughout the year. In ideal situations, their numbers may reach 30 to 40 gophers per acre. They cause tree damage or death by girdling roots or crowns at or below the soil level (2).

Control:

Habitat modification to remove vegetation will discourage gophers.

No chemical or mechanical repellents effectively control pocket gophers.

Trapping – Traps placed in the burrows are effective for small populations. Trapping is time consuming and expensive.

Chemical:

- **Strychnine** – 0.5% bait. Placed in the burrow by use of mechanical burrow builder or with hand probes. Used on 7% of the acres at an average rate of 0.07 lb. a.i. per acre (4). Usually very effective with virtually no secondary wildlife hazards.

- **Chlorphacinone** and **Diphacinone** – 0.005% and 0.01% baits. Applied to burrows in the same manner as strychnine. Used on >0.1% of the acres at an average rate of 0.00013 lb. a.i. per acre (4).

Meadow Mice,
Microtus californicus

Meadow mice are likely to be found wherever they find food and cover such as weeds or ground covers. They may partially or completely girdle trees by feeding on the bark and cambium layer of the trunk anywhere from just below the soil line to as far up the trunk as they can reach. Young trees are attacked more readily and sustain the greatest damage. Full-grown meadow mice are larger than house mice but smaller than Norway or roof rats. Their presence can be recognized by networks of small runways through grass or other cover and their numerous shallow burrows. Meadow mouse burrows are distinguished from those made by gophers because meadow mice do not plug entrance holes (2).

Controls:

Cultural:
Making the orchard and surrounding habitat unfavorable to their development by keeping weed growth down is helpful. Clearing mulches, vegetation, and trash away from the tree trunk to a radius of 1 meter by hoeing or mowing or using herbicides will also reduce or prevent damage.

Place ¼- or ½ inch mesh hardware cloth around the trunk.

Chemical:

- **Zinc phosphide** Applied to <0.1% of the acreage. Spot treatments make it difficult to determine how much was used. A total of 7.1 lb. was used in 7 applications (4).

Ground Squirrels,
Spermophilus beecheyi

California ground squirrels are medium-sized rodents up to 20 inches long measured from the head to the tip of the tail. Ground squirrels cause significant damage in orchards throughout the state. California ground squirrels live in underground burrows where they form colonies of 2 to 20 or more animals. They adapt well to human activities and are found along road or ditch banks, fence rows, and within or bordering many agricultural crops. They are primarily herbivorous. During early spring they consume a variety of green grasses and other herbaceous plants. When these plants begin to dry and form seeds, the squirrels switch to seeds, grains, and nuts.

Squirrels dig extensive burrow systems, bringing soil and rocks to the surface, creating mounds, which may cause damage to orchard equipment.

Control:

Habitat modification by removing piles of orchard prunings and other harborage offers little relief, although, this does make monitoring of squirrel activity easier.

Trapping is impractical and time-consuming, except with small populations (2).

Chemical:
Fumigation with gas cartridges can be effective in spring and early summer when soil moisture is high enough to retain the concentrations of toxic gases. Fumigation is ineffective in summer, particularly when the adult squirrels are aestivating (summer hibernation) because they seal themselves in the nest chamber (2).

- **Aluminum phosphide –** The only fumigant that has shown some degree of effectiveness. Time consuming to hand treat burrows with pellets and seal hole. Requires repeat treatments for effective control. Applied to 2.65% of the acres at a median rate of 0.04 lb. a.i. per acre (4).

- **Strychnine** – 0.5% baits. Must be used in bait boxes. Strychnine is highly toxic to non-target mammals and birds. (See pocket gophers)

- **Brodifacoum** – 0.01% baits. No use data available. A single feeding of this anticoagulant will kill squirrels.

- **Chlorophacinone** – 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows). (See pocket gophers)

- **Diphacinone** – 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows). (See pocket gophers)

Deer,
Odocoileus hermionus and Odocoileus hemionus bolumbiarius

Deer are most numerous in coastal and foothill growing districts, but they also may occur in valley orchards near wooded areas in stream bottoms. Some deer are permanent residents of the vicinity; others migrate from upper elevations to spend winter and spring around the orchard. Deer can completely strip foliage and twigs from young trees and break young limbs off trees while feeding. Repeated feedings may severely stunt young trees. In mature orchards, deer feeding on blossom clusters and tender shoots can significantly reduce crop yield. Surprisingly, fruit feeding is usually not considered an important problem (2).

Controls:

Cultural:
Fencing to eliminate deer from the orchard must be properly built. Wire spacing should not exceed 12 inches and the fence's bottom edge should be fastened to the ground. High-tensile electric wire fences are stronger, more resilient, and cheaper than other fencing. Woven mesh fences are also effective if high enough and properly maintained (2).

Noise making devices may work for a short period but deer soon adjust to them (2).

Depredation after obtaining a permit will provide short term control (2).

Chemical:
Repellents are generally not considered effective (2).

Jackrabbits,
Lepus californicus

Jackrabbits damage young trees by feeding on buds, gnawing the bark from trunks, and clipping off small branches (2).

Controls:

Cultural:
Exclude jackrabbits by building an electric or rabbit proof fence completely around the orchard (2).

Tree guards made of various materials will prevent damage (2).

Shooting and use of repellents may not be feasible in the long term because jackrabbits threaten only young trees (2).

Chemical:
Anticoagulant baits are effective and often used because they are relatively safe for humans and pets (2).

Porcupines,
Erethizon dorsatum

Porcupines primarily damage trees by feeding on the tender foliage of top shoots. To reach foliage in the tops of young trees, a porcupine may break many branches; usually those are left uneaten (2).

Controls:

Biological:
Shooting effectively eliminates porcupines from orchards (2).

Trapping by government trappers is also an option in some areas (2).

Chemical:
Toxic baits are not particularly effective (2).

Birds

Scrub Jays, *Aphelocoma coerulescens*

House Finches, *Carpodacus mexicanus*

Birds that most frequently cause damage in apple orchards are scrub jays and house finches. Scrub jays damage crops by pecking large holes in the fruit as it nears maturity. Jays occur singly or in pairs;

occasionally, however, in response to food sources, they may be found in flocks of up to 50 birds. House finches feed on fruit buds during winter, or embryonic fruit during bloom, and even fruit as it ripens. Damage is usually confined to localized areas of the orchard but nonetheless serious damage can occur from this pest (2).

Controls:

Cultural:
House finches can often be managed by habitat modification such as removing brush piles, bin piles, and irrigation pipe to disturb nesting areas (2).

Shooting, after acquiring a depredation permit from the Fish and Wildlife Service, is effective for managing scrub jays (2).

Frightening devices provide only temporary relief for scrub jays and are not effective against house finches (2).

House finches can be effectively trapped by using a modified crow trap (2).

Chemical:
Baiting is effective against house finches but not effective against scrub jays (2).

Research Efforts

Tebufenozide – *Not registered on apples. An insect growth regulator highly selective for lepidoptera. Moderately effective on codling moth but very effective on leafrollers. A high priority for registration because it fits well in a mating disruption program (7).*

Diflubenzuron - *Not registered on apples. An insect growth regulator with fair selectivity. Moderately effective on codling moth but exhibits cross-resistance to azinphos-methyl resistant codling moth (5). Effective on leafrollers. A high priority for registration because it fits well in a mating disruption program (7). May cause woolly apple aphid outbreaks. This material cannot be used with Trichogramma inundative release or importation of natural enemies.*

Tebufenozide – *Not registered on apples. An insect growth regulator highly selective for lepidoptera. Moderately effective on codling moth but very effective on leafrollers. A high priority for registration because it fits well in a mating disruption program (7).*

Phenoxycarb- *Not registered on apples. An insect growth regulator highly selective for lepidoptera. Moderately effective on codling moth but more so on leafrollers. A high priority for registration because* *it fits well in a codling moth mating disruption program (7)*

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