

Crop Profile for Pistachios in California

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General Production Information

- California entered the world pistachio market in 1976 with its first commercial crop of 1.5 million pounds grown on less than 1,500 acres. This placed the United States fifth among pistachio producers behind Iran, Syria, Turkey and Greece. Only Italy produced less. (4)
- Within a decade the California industry grew to become the second largest producer in the world. (4)
- Currently, more than 83,000 acres are planted throughout the state, with 65,000 acres producing. (4)
- The 1998 harvest yielded a record 187.5 million pounds. (4)
- California produces more than 99% of U.S. pistachios. Arizona's production is still in its infancy. (4)

The pistachio, a member of the same botanical family as the cashew and mango, is a native of Asia Minor. It is a deciduous plant that thrives in climates offering cool, wet winters and long, hot, dry summers. It is tolerant of a wide range of soils but produces best on well-drained, deep, light sandy loams with a high lime content. Though of desert origin, mature trees in commercial production have a high water requirement.

To produce pistachios commercially requires a high initial capital investment and a long wait. Pistachios require about a \$15,000/acre initial investment and then a seven to ten-year wait before the trees reach full bearing and offer the grower a return on the investment. Pistachio trees are alternate bearing, producing a large crop one year and a smaller crop the next. Being wind pollinated, one male tree is planted for every 8 to 24 female trees, which produce the nuts.

California pistachios are of the Kerman variety. Beginning with the state's first plantings, scientists strengthened the Kerman by budding it to more resistant rootstocks. California now has four different rootstocks, helping the resulting tree adapt to disease and climate.

Pistachio tree production begins in a nursery. Rootstock seeds are germinated in January, grown for fifteen months in pots, and sold to growers for planting in orchards during early spring; budding is performed in midsummer. The young, nonbearing tree is trained to the adult tree shape for 5 to 7 years and begins producing small crops at 5 to 6 years.

The annual pistachio growing season begins in late March when buds formed the previous summer begin to swell. Bloom occurs in April, with foliage and shoot growth then emerging in early May.

During May, the shells expand inside the hull. By June when the shells have reached full size, they begin to harden. However, the nuts within the shells have not yet developed; nut-fill typically occurs during July. (The timing of all developmental stages may vary according to environmental conditions.)

Upon completion of nut-fill, the enlarged nut causes the shell to split naturally. The hull, the protective covering over the shell, remains intact, but removes easily when pinched. The crop is ready for harvest when the nuts fall easily as the cluster is shaken. Harvest is timed to obtain the maximum number of split nuts, usually beginning in early to mid-September. Because rapid processing upon harvest is crucial to resulting nut quality, the industry works around the clock for the six to eight weeks of harvest.

Mature pistachios require care throughout the year. During the growing season, April through October, they require fertilization, irrigation, weed control for the orchard floor, insect and bird protection for the nuts, and disease control for the foliage and roots. During the dormant season, November through March, they require pruning to generate new fruiting wood and to maintain tree size. Because pistachios are still a relatively new and unique crop to California, growers continue to face new challenges.

Insect Pests

Navel Orangeworm, *Amyelois transitella*

Navel Orangeworm (NOW) is considered the most important insect pest problem in pistachios. NOW moths deposit eggs on the outer hull of the developing pistachios. Upon hatching from eggs, the larvae of NOW will infest the nutmeats if there is any damage to the outer hull protecting the shell and the nuts. The larvae produce excrement (frass) and webbing in the nut. Often more than one worm can often be found eating the nut. Infested nuts are prime sites for *Aspergillus* mold infections, which produce aflatoxin contaminants (potent carcinogens). Crop damage from this pest can reach levels of 5% or more, which, combined with the strict limits on aflatoxin contamination in nuts, requires management of NOW. NOW occurs throughout California.

Factors that cause early hull split result in increased NOW infestation. The hard shell naturally splits open during ripening leaving the nut only protected by the outer hull. However, sometimes as the shell splits the hull also splits (•early splits•). Wind or insects can damage the hull. It appears that diseases such as *Alternaria alternata* increase the incidence of NOW by weakening the hull.

Almond orchards often border pistachio plantings. Almonds are harvested a month earlier than pistachios and moth movement from orchard to orchard is common. Early harvest, a technique available

in almonds to escape NOW infestation, is not an option in pistachios because pistachios must remain on the trees for immediate processing after harvest. The nuts cannot be left on the soil surface to dry. (2,3)

Controls:

The primary management technique for NOW is winter removal of unharvested nuts from the trees and the ground. The moth requires nuts (almonds, pistachios, or walnuts) to survive the winter. In the spring growth starts again and infestation of the next crop starts. Factors such as citrus flat mite infestation or disease can increase the number of nuts remaining on the tree which will accentuate the NOW problem. The removal of •mummy• nuts is more easily accomplished on smaller trees (<20 feet in height) than taller trees.

Egg traps filled with almond press meal (90% by weight) and almond oil (10% by weight) are used to detect population trends for NOW. Insecticides are used based on the NOW population trends and the amount of hull damage. Insecticide control of NOW is more effective in pistachios than in almonds. Often a single well-timed application can reduce infestation by 65 to 75 percent. These applications are timed to the onset of hull split, shortly before harvest, when the nuts first become susceptible. The preferred application method is by air blast ground sprayers. Aerial applications (if allowed) are occasionally used when it is not possible to drive in the orchard. (2,3)

Chemical Control:

- Azinphos-methyl is the primary NOW insecticide in part because of its long residual. It is applied at 2 lbs a.i./acre once per season at hull split. Use is limited to one application per season. Azinphos-methyl has a 21-day PHI. No secondary pest problems have been observed in pistachios. There have been no studies on resistance. In 1997, 29,374 lb a.i. were used to treat 17.15% of the acreage 1 time at a median application rate of 2.0 lb a.i./acre. (1)
- Phosmet has become more widely used to control NOW and is used similarly to Guthion. It is a relatively short-lived organophosphate, remaining active for approximately 10 days at the recommended rate of 2.5 lbs a.i./acre. It has a 14-day PHI. Phosmet requires buffering to a pH of 5 for effective results. No secondary problems have been seen with this material. In 1997, 25,680 lb a.i. were used to treat 7.89% of the acreage 1 time at a median application rate of 3.5 lb a.i./acre. (1)
- Carbaryl is periodically used for NOW control at the rate of 4 to 5 lbs a.i./acre. It has a 14-day PHI, shorter than azinphos-methyl, and can be used if unexpected worm infestation is detected. In 1997, 11,918 lb a.i. were used to treat 3.89% of the acreage 1 time at a median application rate of 1.6 lb a.i./acre. (1)
- Permethrin is used for NOW at 0.2 to 0.4 lbs a.i./acre. Because it is a primary material for other pests such as stink bugs and phytocoris, many orchards may be repeatedly treated with this material. For NOW control, application occurs from hull split to harvest, since it has a 0-day PHI.

In 1997, 11,208 lb a.i. were used to treat 39.81% of the acreage 1 time at a median application rate of 0.2 lb a.i./acre. (1)

- *Bacillus thuringiensis* has not been effective.

Biological Control:

NOW is parasitized by *Goniozus legneri*, and *Copidosomapsis plethorica*. Neither of these parasitoids alone has provided economic control of NOW.

Future Control Techniques:

- New approaches to management of NOW involve the release of a pheromone into orchards to disrupt mating. This technique is currently under development and should be useful where there are large contiguous blocks of pistachios. However, this technique will not control moths moving into pistachios orchards at the end of the season from neighboring orchards. Thus it may not be effective in smaller blocks or where there is no control of NOW on neighboring land.
- Spinosad (unregistered) looked promising against NOW in 1998 efficacy trials. However its short residual may require either multiple applications or applications closer to harvest.
- Tebufenozide (unregistered) showed some efficacy against NOW in 1998 trials, but further research is needed.

Obliquebanded Leafroller (OBLR), *Choristoneura rosaceana* (Harris)

The obliquebanded leafroller is a native North American insect which attacks a wide range of fruits and nuts. Hosts include apple, pear, peach, prune, plum, walnut, almond, and pistachio. The overwintering larvae will feed on newly formed leaves and clusters. The primary damage is through defoliation. OBLR infestation occurs throughout the state and in the last several years has become a more serious problem in pistachios. Once established in the orchard it can develop into an annual problem. (2,3)

Controls:

Sampling in the spring is done by visual examination of the leaves. In late April the adult moths can be trapped using OBLR synthetic pheromone traps. Such trapping has allowed development of flight curves for males to determine timing of control treatments.

The two month generation time of OBLR combined with its habit of webbing leaves around itself for protection, has made chemical control difficult. To be effective insecticide applications must be carefully timed to reach the larval stage. Treatment may occur in May to control overwintered larvae and July through August to control the second generation. (2,3)

Chemical Control:

- Permethrin is most commonly used to control OBLR. It is applied at 0.2 to 0.4 lbs a.i./acre. Permethrin promotes the development of webspinning spider mites, for which there is currently no registered control material in pistachios. It is also hard on beneficials. (See navel orangeworm.) (1)
- Phosmet is starting to be more commonly used to control OBLR. It performed well in trials completed in 1998. (See navel orangeworm.) (1)
- Carbaryl is periodically used for OBLR control. (See navel orangeworm.) (1)
- Azinphos-methyl is infrequently used against OBLR, because its use is limited to once per season. (See navel orangeworm.) (1)
- *Bacillus thuringiensis* provides partial population reduction but must be applied prior to leaf rolling and requires multiple applications. Leaf rolling occurs in the spring before flights can be monitored and therefore these applications must be made before knowing if there is a problem present. It is useful where mild OBLR populations occur. In 1997, 10 lb a.i. were used to treat 1.59% of the acreage 1 time at a median application rate of 0.02 lb a.i./acre. (1)

Future Control:

- Spinosad (unregistered) provided excellent population reduction in 1998 research trials.
- Research to develop a mating confusion technique to manage OBLR is being done in other crops but this approach is not currently available in pistachios. Mating confusion techniques would be well adapted to pistachios, which are planted in large contiguous blocks and are relatively isolated from other host crops.

Western Tussock Moth, *Orgyia vetusta* (Boisduval)

Western Tussock moth is a relatively minor problem that is present in orchards throughout the state. It produces one generation per season. Wintering eggs (as many as 300 per wintering egg cluster) hatch in the spring when leaves begin to emerge. High populations can quickly defoliate orchards prior to fully leafing. (2,3)

Controls:

Western Tussock moth populations will vary from year to year and can be controlled by parasitoids. If the orchard is regularly treated for other pests, these parasitoids will not be present. Visual monitoring is the only method available to determine the presence of this pest. There are no established thresholds for Western Tussock moths. (2,3)

Chemical Control:

- Permethrin is most often used at 0.2 to 0.4 lbs a.i./acre. Application in the spring will also reduce populations of *Phytocoris relativus* Knight and *Neurocolpus longirostris* Knight. (See navel orangeworm.) (1)
- Carbaryl is used occasionally for Western Tussock moth control. (See navel orangeworm.) (1)
- Phosmet is used occasionally. (See navel orangeworm.) (1)
- Azinphos-methyl is rarely used, since use is limited to once per season and use is preferred for NOW control. (See navel orangeworm.) (1)
- In instances when Western Tussock moth is found early, before larvae are more than a third grown, *Bacillus thuringiensis* applied at 1 to 1.5 lbs/acre is effective. Once larvae are larger, the defoliation they cause must be stopped quickly with contact materials. (See obliquebanded leafroller.)

Biological Control:

Natural parasitoids include tachinid flies, a dermistid beetle, and several groups of parasitic Hymenoptera.

Small Plant Bugs

Calocoris norvegicus,

Lygus hesperus

Psallus vaccinicola

Neurocolpus longirostris

Phytocoris relativus

Each of the species included in the small plant bug group is considered a sporadic pest. Although these insects do not cause damage annually, yields can be reduced dramatically when high populations are present. They are unable to penetrate the shell once it hardens in mid-June. Consequently damage occurs for a relatively short period of time, between nut formation in April and shell hardening in June. The damage can be exacerbated in the "off" production years when nut yield is low. (2,3)

Recently, the ability of the small plant bugs to cause wounds, which provide entrance for the devastating fungus, *Botryosphaeria dothidea*, has increased concern about these pests.

Controls:

A beating tray and club is used to sample for the plant bugs. The bugs are dislodged by the club and caught on the tray, held below the clusters. Blackened nuts (epicarp lesions) are also an indication that feeding is occurring. There is no specific threshold for treatment based on the number of plant bugs found. The decision to spray is based on the progression of nut damage and the presence of a particular pest.

There are no known parasitoids or predators that effectively regulate populations of these insects. Environmental conditions strongly influence the populations of both lygus bug and calocoris. Wet years, which encourage germination of bur clover, vetch, lupine, trefoil, tarweed and Russian thistle, create conditions that favor small plant bug survival. Later, as these plants dry, the small plant bugs move into pistachios. (2,3)

Chemical Control:

- Permethrin is applied at 0.2 to 0.4 lbs ai/acre. The vast majority of its use is to control both small and large plant bugs. Depending on insect presence, applications occur from the end of April to mid June. In a season, 0-3 applications may be applied. However, permethrin may cause spider mite problems and is particularly harsh on beneficial insects. (See navel orangeworm.) (1)
- Carbaryl is occasionally used. (See navel orangeworm.)
- Neither phosmet nor azinphos-methyl is effective against plant bugs.
- *Bacillus thuringiensis* is not effective against plant bugs.

Large Plant Bugs

Redshouldered plant bug, *Thyanta pallidovirens*

Southern green plant bug, *Nezara viridula*

Green soldier bug, *Acrosternum hilare*

Uhler's plant bug, *Chloracroa uhleri*

Leaffooted plant bug, *Leptoglossus clypealis*

The large plant bugs are also sporadic pests of pistachios, but can damage the crop throughout the growing season. Feeding early in nut development will result in nut abortion. Feeding after shell hardening causes a disorder known as kernel nut necrosis. If yeast or bacteria are present on the mouthparts of feeding insects, a condition known as stigmatomycosis may develop, which causes the

meat to soften and become rancid. As with the small plant bugs, wounds caused by feeding have been demonstrated to provide an entrance for the disease *Botryosphaeria dothidea*.

A wide range of plants are host to these insects. For the leaffooted plant bug, juniper and cypress are hosts. The primary host for Uhler's plant bug is Russian thistle, which is also a primary mid-season host for *Lygus hesperus*. The redshouldered stink bug is found in association with London rocket and a range of wild mustard and wild radish host plants. (2,3)

Controls:

Monitoring for stink bugs and leaffooted plant bugs within the orchard is done with a beating tray and club, just as with the smaller plant bugs. These larger bugs are not as efficiently sampled as are the smaller bugs because the larger bugs are often found higher in the tree and cannot be reached. When growers find damaged nuts but not bugs, they will apply treatment for the larger plant bugs. (2,3)

Chemical Control:

- Permethrin is the most effective insecticide for control of the large plant bugs. (See navel orangeworm, small plant bugs.)
- Carbaryl is occasionally used at a rate of 5 lbs ai/acre, particularly if NOW is a concern shortly before harvest. (See navel orangeworm.)

Biological Control:

Biological control of the stink bugs can periodically regulate populations. Naturally occurring? Egg parasitoids are primarily responsible. The most common are *Trissolcus* spp. *Gryon pennsylvanicum* is a common egg parasitoid of the leaffooted plant bug. In some years, it can regulate late season populations of leaffooted plant bug. Other parasitoids, including a tachinid fly, parasitize adult stink bugs.

Future Control:

Currently, research, funded by the California Pistachio Commission, has discovered pheromones for a few of the stink bugs, which will allow for the development of better monitoring of these key pests.

There is a need for less disruptive, more selective insecticides for hemipteran pests.

Soft Scales

Frosted scale, *Parthenolecanium pruinosum*
European fruit lecanium, *Parthenolecanium corni*

These two species of unarmored scale have become the dominant scale insect pests in pistachios in recent years. Both species have numerous host plants. These scales only have one generation per year

and overwinter on twigs and limbs as nymphs. With the warmer temperatures of spring the nymphs start to feed and grow again. Scales are most common on vigorously growing trees and are normally kept under control by native parasites and high summer temperatures. When populations do build up, heavy amounts of honeydew can affect photosynthesis and provide a substrate for sooty mold. Moderate to high scale populations can also retard shoot growth and shell splitting.

Soft scales molt twice before they reach maturity. The stage just before adult molting is frequently referred to as the rubber stage. In this stage, the scales remain soft, somewhat translucent, and are still susceptible to parasites and insecticides. Upon molting to adults, the shell hardens and becomes opaque reducing the effectiveness of insecticides and parasites. (2,3)

Controls:

An effective parasite of soft scales is a tiny parasitic wasp, *Metaphycus luteolus*, which destroys the scale in its early instars before it can reproduce or cause substantial injury. This parasite produces several generations. In addition, other parasites such as the predacious lady beetle, *Rhyzobius* (Lindorus) *lophanthae*, prey on these scales.

Chemical Control:

- Carbaryl requires 4-5 lbs a.i./acre plus 6 gallons of Volck Supreme spray oil per acre applied in the late dormant period (usually mid-February) to provide effective control. Carbaryl alone during the growing season will also provide effective control. Around 5% of acreage is treated for scales in any given year since it seems that control lasts for several years. The loss of either carbaryl or Volck oil would leave the pistachio industry without any control for soft scales. (See navel orangeworm.) (1)
- In 1997, 1,059,430 lb a.i. horticultural oils were used to treat 30.56% of the acreage 1 time at a median application rate of 42.35 lb a.i./acre. (1)

Future Control:

The insect growth regulators pyriproxyfen and buprofezin may be efficacious.

There is a need for a selective scale material.

Striped Mealybug, *Ferisia virgata*

The striped mealybug was discovered in 1998 infesting two orchards in Tulare County. This was a new host record for this pest, which has the potential to become a serious pest.

Current Management and Cultural Practices:

There are no cultural, chemical or biological controls available or known at this time.

Mites

Citrus Flat Mite, *Brevipalpus lewisi*

Citrus Flat Mite (CFM) populations are very sporadic and most commonly build up to damaging levels during the summer. However, low populations cause severe damage in pistachios. CFM feed in nut clusters, not on leaves. Stems and nuts shrivel under heavy population pressure. Also, the damaged nuts have an increased tendency to remain on the tree after harvest and serve as an overwintering habitat for navel orangeworm. CFM prefers to feed out of direct sunlight inside the tree canopy, on the under side of clusters. The nuts and rachis will take on a black "greasy" appearance after CFM feeding. (2,3)

Controls:

Any insecticide that interferes with the beneficial population may increase the population of CFM. Generalist predators such as lacewing larvae, sixspotted thrips, and predatory mites can feed on CFM. However since low CFM populations can cause significant damage, the time lag for predator populations to control CFM limits the usefulness of parasites.

No precise guidelines are available to determine the need for chemical treatment. Treatment should occur when CFM can be easily found in clusters but before damage occurs. (2,3)

Chemical Control:

- Sulfur dust has a 0 day PHI and is applied at a rate of 16 to 20 lbs a.i./acre. Wettable sulfur has a 0 day PHI and is applied at a rate of 8-16 lbs a.i./acre in sufficient gallonage to achieve thorough coverage. Sulfur is usually applied once per season. In 1997, 589,813 lb a.i. were used to treat 43.76% of the acreage 1 time at a median application rate of 11.64 lb a.i./acre. (1)
- No other registered insecticide provides control of CFM.

Pacific Mite, *Tetranychus pacificus* Twospotted Mite, *Tetranychus urticae*

Spider mites are only occasional pests, but when present can be very damaging. As few as 2 to 3 mites per leaf can cause defoliation in pistachios, and when this occurs trees will not leaf out again until the following season. Spider mites overwinter as adult females in the trees or on the orchard floor. The mites most commonly develop into a problem after in-season insecticide treatments, especially with permethrin or carbaryl, which damage predators of the mites. (2,3)

Controls:

Since the mites prefer dry, dusty conditions, cultural controls include minimizing dust by oiling orchard roads, and optimizing tree vigor through proper nutrition and irrigation regimes. Counting the percentage of leaflets infested monitors spider mites. When leaves examined for mites have necrosis because of a spider mite infestation and predator activity is minimal or nonexistent, chemical treatment is warranted. Populations usually appear in late May or June. (2,3)

Chemical Control:

- Neem Oil + other components: PHI - 0 days. Apply 0.5 to 2.0% in 30 to 250 gallons of water per acre. Need a solution of sufficient volume to achieve complete coverage of foliage. In-season oils treatments are effective, but must be used very cautiously to avoid phytotoxicity. It cannot be applied after sulfur, copper or zinc containing compounds. In 1997, 130 lb a.i. were used to treat 0.1% of the acreage 1 time at a median application rate of 1.5 lb a.i./acre. (1)
- Sulfur is not effective against Pacific or Twospotted mites.

Biological Control:

Predators play an important role in keeping populations below damaging levels. The most common predators are predator mites. Other predators may include sixspotted thrips, the minute pirate bug, lacewing larvae, and the spider mite destroyer. Use of synthetic pyrethroids and carbamates can be especially damaging to predator populations. (2,3)

Future Control:

- Pyridaben may be effective.
- Bifenazate may be effective.

Note: There is a current need for a selective acaricide for pistachio.

Post Harvest Insect Control**Stored Nuts**

Indian Meal Moth, *Plodia interpunctella*
Navel Orangeworm, *Amyelosis transitella*

Red Flour Beetle, *Troboium spp.*
Confused Flour Beetle, *Troboium spp.*
Warehouse Beetle, *Trogoderma variabile*
Cigarette Beetle, *Lasioderma serricorne*

Dried pistachios are fumigated after harvest for control of navel orangeworm, ants, moths and other storage pests. Navel orangeworm damage is directly correlated with the contamination of pistachios with aflatoxins. Control of these insects is critical to maintain markets that demand insect-free pistachios. Many countries require fumigation prior to export for control of pests that could be present and to prevent infestations en route.

All pistachios are fumigated after dehulling and drying upon initiation of storage. Fumigations are repeated during storage every 1-3 months depending on temperatures and pest pressures. Most pistachios are fumigated just prior to shipping, especially for export markets.

Chemical Control:

- Aluminum Phosphide is administered in either 100-200 pellets or 20-40 tablets (55% AIP)/1000 cu ft. Fumigation takes 2-3 days minimum. In 1997, 2,573.34 lb a.i. were used to treat pistachios, facilities, and other non-acre units. (1)
- Methyl Bromide is used to fumigate nuts in chambers when shorter fumigation times are desired and for certain export markets. A rate of 1 lb/1000 sq ft is used. In 1997, 6,682.43 lb a.i. were used to treat pistachios, facilities, and other non-acre units. (1)

Processing Facilities

To prevent moths and beetles from infesting the processed nuts, processors regularly use insecticides inside the premises to reduce the insect populations. The insects are attracted by the lights when processing is occurring during the night and can reproduce in processing debris. Both foggers and crack and crevice treatments are used. A fogger is placed on a timer to provide 0.5 oz of active ingredient per 1000 ft³ during times when no one is present (nights or weekends).

- DDVP is used for fogging to control flying and crawling insects and stored product pests. It also provides some rodent control. Its use has decreased since the institution of a 24 h re-entry period. In 1997, 2.24 lb a.i. were used to treat pistachios, facilities, and other non-acre units. (1)
- Pyrethrin is used with a fogger to control flying and crawling insects. It is supplied in 0.1-6% concentrations. It has little odor and no re-entry limitations, but is relatively more expensive. Pyrethrin was not used in 1997. (1)

- Resmethrin is used with a fogger to control flying and crawling insects. It is supplied as 0.5-3% concentrations. Its strong odor limits its use, but it has no re-entry limitations. Resmethrin was not used in 1997. (1)
- Hydroprene is an insect growth regulator that provides longer-term insect control. However, its effects are not immediate and it is relatively costly. Hydroprene was not used in 1997. (1)

Diseases

Botryosphaeria panicle and shoot blight, *Botryosphaeria dothidea*

The fungus attacks all current season growth and kills buds, shoots and fruit clusters. The pathogen survives in infested buds and in old infections where it forms cankers. The cankers can produce inoculum for several years. It is readily spread by rain and to some extent by certain insects and birds. The fungus also attacks many other species including wild and domesticated plants, although pistachio was identified as a host for the first time in the late 1980's. Although the tree is not killed, a severe outbreak of this disease renders the tree completely unproductive. The disease is especially damaging to the widely planted cultivar 'Kerman'.

Control is difficult and often inadequate, allowing the disease to build up to unmanageable levels. Current efficacy data show that multiple fungicide applications during the whole growing season are necessary to achieve some level of control. The disease grows throughout the season, with a particular fondness for killing the nut-bearing clusters just before harvest. *Botryosphaeria* infected nuts remain on the tree and can become a host to overwintering navel orangeworm. (2,3)

Controls:

A combination of pruning, irrigation management, and use of available fungicides provided only marginal control. Early detection and immediate control measures are critical to prevent the disease from becoming endemic in an orchard. Pruning is very useful for removing sources of inoculum, however pruning not only removes current year growth, but also the shoots and flowers for the next year. (2,3)

Chemical Control:

Registered fungicides are ineffective and emerging fungicides require multiple applications. Fungicide applications are usually by air blast ground sprayers. Aerial applications are occasionally used for benomyl when it is not possible to drive in an orchard.

- Benomyl is applied at 0.75 to 1 lb. a.i./acre. It may only be applied once at bloom. In 1997, 6,234 lb a.i. were used to treat 9.23% of the acreage 1 time at a median application rate of 0.78 lb a.i./acre. (1)
- Copper hydroxide is completely ineffective against *Botryosphaeria*.
- Azoxystrobin was registered under a special local need registration in 1999, thus there is no field experience yet. Initial trials showed azoxystrobin to be fairly effective against *Botryosphaeria*. Applied at 12.8 fl oz (0.013 lb a.i.)/acre. 28 day PHI. It may be applied 6 times in a season, however only 3 sequential applications are allowed before rotating with another material. Because there is no rotational material currently available, there are serious concerns about rapid resistance development.

Future Control:

Tebuconazole currently has a pending registration with EPA. Applied at 0.14-0.23 lb a.i./acre. 20 day PHI. In 1997 and 1998 there were Section 18 registrations for three and four applications after bloom, respectively. Under severe disease pressure, four applications of tebuconazole was not sufficient for acceptable control. In 1997, 10,676 lb a.i. were used to treat 28.01% of the acreage 2 times at a median application rate of 0.23 lb a.i./acre.

Note: There is a current need for fungicides for this disease, not only for adequate control, but also resistance management. Several compounds are currently under study.

Botrytis shoot blight, *Botrytis cinerea*

Botrytis shoot blight infections occur in early to mid-spring and are associated with cool, wet weather. The fungus invades the base of the young shoot, killing it. Infected succulent shoots wilt causing the tips to curve in a characteristic shepherd's hook. Male inflorescences also are attacked and killed, and the disease typically is worse in male than in female trees. The loss of pollen can adversely affect yield. The pathogen survives on dead plant organic matter, and its conidia are wind disseminated. (2,3)

Current Management and Cultural Practices:

The disease is controlled by fungicide applications during bloom.

Chemical Control:

- Benomyl is applied at 0.75 to 1 lb. a.i./acre at bloom. (See *Botryosphaeria*.)

Future Control:

Cyprodinil + Fludioxonil is being tested.

There is an immediate need for additional registered fungicides for control of this disease. Several compounds are currently under study.

Alternaria late blight, *Alternaria alternata*

The pathogen attacks leaves and fruit but the primary damage is to leaves, which shed early causing debilitating defoliation. The disease develops in mid to late summer and continues into fall. It is associated with areas of high humidity and repeated dew events. The fungus is a common saprophyte that is pathogenic to mature and senescing tissues. It survives on any dead plant organic matter and its conidia are spread by wind. Orchards sustaining repeated premature defoliation may decline in productivity. (2,3)

Controls:

Altering irrigation practices can reduce the disease. Registered fungicides through 1998 had limited effect. Section 18 registrations have been granted for the use of iprodione and then tebuconazole.

Chemical Control:

- Azoxystrobin (See *Botryosphaeria*.)
- Copper hydroxide applied at 6.16 lbs a.i./acre will give partial control with repeated applications. Control has not been commercially acceptable. In 1997, 18,988 lb a.i. were used to treat 2.88% of the acreage 1 time at a median application rate of 4.62 lb a.i./acre. (1)
- Benomyl has an application restriction to bloom, preventing benomyl from being effective against *Alternaria*, which is a warm-temperature disease.

Future Control:

Tebuconazole is pending registration at the EPA. (See *Botryosphaeria*)

There is a current need for registered fungicides for this disease. Several compounds are currently under study.

Phytophthora trunk and branch canker, *Phytophthora capsici*, *P. cryptogea*, and *P. parasitica*

The rootstocks on which pistachio trees are propagated in California are extremely tolerant to the

Phytophthora root and crown rot fungi. Although the pistachio scion is very susceptible, and infected trees die, the disease is uncommon. The pathogens are present in most rivers and canal water, and if during irrigation such water is directed into the upper part of the tree, infection is likely. Floodwaters also may carry the fungus into the scion. (2,3)

Controls:

Irrigation management and resistant rootstock control the disease. No fungicide control is recommended.

Note: There are no chemical controls at this time.

Verticillium wilt, *Verticillium dahliae*

The Verticillium wilt pathogen is a widespread soil-borne fungus that attacks hundreds of plant species. They can survive in the soil for many years with or without the presence of susceptible hosts. It invades the small roots, just behind the root tip, then colonizes the xylem elements, thereby disrupting the flow of water through the plant. The disease assumes two forms, one form causes a rapid collapse and death of part or all of the tree and the other form is a slow decline that eventually leads to tree death. Up to 100% tree loss can occur in plantings on susceptible rootstocks. (2,3)

Control:

Most rootstocks are susceptible, but two are functionally resistant and use of these rootstocks is the best control available.

Soil fumigation or solarization has not been successful in controlling this disease in pistachios.

Note: There are no chemical controls at this time.

Weeds

Weeds compete with trees for water and nutrients. They can exacerbate vertebrate and insect problems and aid in the development of the diseases Alternaria and Botryosphaeria by increasing the humidity in the orchard. Soil characteristics have a significant effect on the weed species present.

Controls:

Most orchards use a variety of control techniques depending on the location in the orchard. The main

row between trees is kept clear of weeds by discing and/or mowing. Some growers use chemical mowing, (i.e., applying a low rate of a herbicide to the rows stunts growth). Herbicide treatments are mainly used for the berms and are applied pre-emergent and/or post-emergent. Typically only 25-33% of an orchard's surface is treated with herbicide. The orchard floor is usually cleaned shortly before harvest.

Pre-emergent herbicides are most commonly used. Residual control of pre-emergent materials is affected by the amount of applied irrigation water or rainfall and by the type of irrigation system used. Post-emergent herbicides are used for spot control or to control weeds emerging on the berms in-season. Certain weeds (yellow nut sedge, flax-leaf fleabane, mare's tail) require multiple applications for control with currently registered herbicides. Conducting weed surveys 2 to 3 times per year can enhance treatment decisions. Application is usually by ground-boom sprayer.

In-season cover crops are no longer used much because of their contribution to disease incidence. Winter cover crops are grown to increase water penetration in certain soil types.

Chemical Control:

- Oxyfluorfen: PHI - 7 days. This herbicide has both pre-emergent and post-emergent activity. It is primarily used during the dormant season for selective pre-emergent broadleaf control at application rates of 1.25 to 2.0 lbs a.i./acre. It also has some uses as a synergist with Roundup in-season. Applications are not permitted from bud swell until May 1. In-season uses are allowed through a special local need registration. In 1997, 40,500 lb a.i. were used to treat 61.74% of the acreage 1 time at a median application rate of 0.51 lb a.i./acre. (1)
- Oryzalin: PHI - 0 days. A pre-emergent herbicide selective for grasses and several annual broadleaves that is applied at a rate of 3 to 6 lbs a.i./acre. It has excellent safety characteristics, even for young trees in light soils. In 1997, 88,521 lb a.i. were used to treat 50.87% of the acreage 1 time at a median application rate of 2.72 lb a.i./acre. (1)
- Napropamide: PHI - 0 days. A pre-emergent herbicide selective for grasses and several annual broadleaves applied at a rate of 3 to 4 lbs a.i./acre. It has excellent safety characteristics, even for young trees in light soils. This compound has poor stability on the soil and must be incorporated by water within a few days of application. In 1997, 1,307 lb a.i. were used to treat 1.35% of the acreage 1 time at a median application rate of 1.0 lb a.i./acre. (1)
- Glyphosate: PHI - 3 days. Typically used at 1-3 pints/acre and applied 1-3 times per season to the berms. A non-selective systemic applied for a broad range of weed species applied anytime of the year. In 1997, 63,298 lb a.i. were used to treat 49.23% of the acreage 1 time at a median application rate of 1.0 lb a.i./acre. (1)
- Paraquat: PHI - 7 days. A post-emergent, non-selective material applied at 0.6 to 0.9 lbs a.i./acre. It is used for rapid burndown, however most perennials and some annuals regrow after treatment.

It is most commonly used with pre-emergents for applications during the dormant season to eliminate existing vegetation. In 1997, 20,664 lb a.i. were used to treat 35.21% of the acreage 1 time at a median application rate of 0.63 lb a.i./acre. (1)

- 2, 4-D: PHI - 60 days. It may only be used during the dormant period. As a post-emergent systemic material selective for broadleaves it is applied at a rate of 1.4 lbs a.i./acre. Numerous counties have specific restrictions regarding the use of 2, 4-D because of hypersensitivity of other crops in the area. In 1997, 12 lb a.i. were used to treat 0.04% of the acreage 1 time at a median application rate of 0.68 lb a.i./acre. (1)
- Pendimethalin: Non-bearing trees only. A selective pre-emergent herbicide, which is applied at a rate of 1.98 to 3.96 lbs a.i./acre. In 1997, 7,087 lb a.i. were used to treat 2.61% of the acreage 1 time at a median application rate of 0.2 lb a.i./acre. (1)
- Sethoxydim: Non-bearing trees only. A systemic post-emergent herbicide, which is selective for annual and perennial grasses, and is applied at a rate of 0.19 to 0.47 lbs a.i./acre or as a spot spray at concentrations of 1.0 to 1.5%. In 1997, 1 lb a.i. was used to treat 0.01% of the acreage 1 time at a median application rate of 0.28 lb a.i./acre. (1)

Future Control:

Thiazopyr (unregistered) is a pre-emergent herbicide, which is effective against nutsedge and other difficult to control weeds.

Vertebrate Pests

Ground Squirrels, *Spermophilus beecheyi*

California ground squirrels are medium-sized rodents that are up to 20 inches long head to tail. They live in underground burrows where they form colonies of two to 20 or more animals. They adapt well to human activity and are commonly found living along road, ditch, and fence banks bordering field and orchards. California ground squirrels feed primarily on green grasses and other herbaceous plants during the early spring. As these dry up and form seeds, the squirrels switch to seeds, grains, and nuts.

Ground squirrels often infest pistachio orchards. They easily climb trees and feed on nuts from fruit set through harvest. Adult squirrels often store seeds and nuts in their burrows, leading to significant harvest losses. In addition, the extensive burrow and mound system creates problems for orchard operations especially harvest and irrigation. Their feeding on limbs will girdle and kill limbs.

Controls:

Habitat modification by removing piles of orchard prunings and other harborage offers little relief. Trapping is impractical and time-consuming, except with small populations. Efforts to provide habitat for owls or raptors, by putting up owl-boxes, have helped control smaller populations.

Chemical Control:

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. It is ineffective in summer, particularly when the adult squirrels are estivating (summer hibernation), because the squirrels create a soil plug to seal themselves in the nest chamber. Any treatment must minimize impacts on other animals. Recent work by CDPR shows that raising the bait boxes a little off the ground makes them available to ground squirrels, but not other rodents.

- Chlorophacinone as 0.005% and 0.01% baits. It requires multiple feedings for 6 days or more. Used in bait boxes or, if the label allows, is broadcast. In 1997, 0.03 lb a.i. was used to treat 1.05% of the acreage 1 time. (1)
- Diphacinone as 0.005% and 0.01% baits. It requires multiple feedings for 6 days or more. Used in bait boxes or, if the label allows, is broadcast. In 1997, 0.08 lb a.i. was used to treat 0.56% of the acreage 1 time. (1)
- Aluminum Phosphide - is the only fumigant that has shown some degree of effectiveness. It is time consuming to hand treat burrows with pellets and seal holes. Repeat treatments are required for effective control. In 1997, 8 lb a.i. were used to treat 0.55% of the acreage 1 time at a median application rate of 0.02 lb a.i./acre. (1)

Pocket Gophers, *Thomomys spp*

Pocket Gophers are stout-bodied, short-legged rodents 6 to 8 inches long. They live almost entirely underground, creating extensive burrows for living and feeding. Their colonies frequently reach a density of 30-40 gophers per acre. Pocket gophers are common in areas of abundant plant growth. They feed primarily on the roots of herbaceous plants.

Pocket gophers frequently live in orchards where they cause tree damage or death by girdling roots or crowns at or below the soil level. They also chew through underground irrigation systems, causing extensive damage. They are active throughout the year.

Controls:

Growers rely mainly on trapping and strychnine for control of pocket gophers. No chemical or mechanical repellents are effective in controlling pocket gophers.

Chemical Control:

- Chlorophacione and Diphacinone (See Ground squirrels.)
- Strychnine as 0.5% baits. It must be used in bait boxes. Strychnine is highly toxic to non-target mammals and birds. 0.5% of acreage was treated with strychnine in 1996. Strychnine is placed in the burrow by use of a mechanical burrow builder or with hand probes. Usually very effective with virtually no secondary wildlife hazards. In 1997, 1 lb a.i. was used to treat 0.13% of the acreage 1 time. (1)

Contacts

Dr. Walt Bentley
Entomologist, IPM Specialist
Kearney Agricultural Center
9240 South Riverbend Ave.
Parlier, CA 93648
tel: 559-646-6527
walt@uckac.edu

Gary Weinberger
Licensed Independent Pest Control Advisor
Research Coordinator for the California
Pistachio Commission
2399 Oakes Lane
Hanford, California 93230
tel: 559-582-3006
garywaac@cnetech.com

Dr. Beth Teviotdale
Plant Pathologist
Kearney Agricultural Center
9240 South Riverbend Ave.
Parlier, CA 93648
tel: 559-646-6538
beth@uckac.edu

California Pistachio Commission
1318 East Shaw Avenue, #420
Fresno, CA 93710
tel: 559-221-8294
www.pistachios.org

Reviewed by:

California Pesticide Impact Assessment Program
University of California, Davis
530/754-8378

Kevin Olsen, Technical Director, S & J Farms;

Dr. Gabriele Ludwig, Schramm, Williams & Associates.

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