

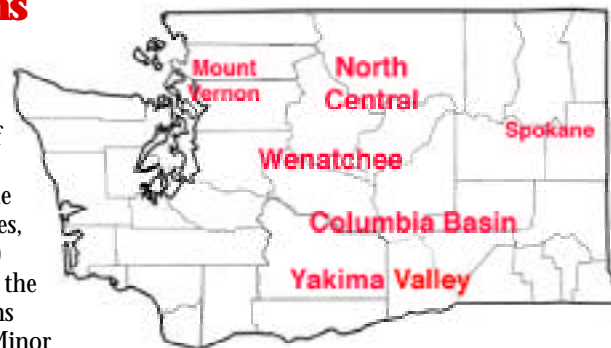
# Crop Profile for **Apples** in Washington

## Production Facts

- ❖ Washington State ranks #1 in the nation in production of apples. Washington growers produce about 53% of the apples grown in the United States, and 66% of those grown for fresh consumption.
- ❖ Apple acreage in Washington is estimated at about 192,000; an estimated 10,000 acres are non-bearing.
- ❖ Apples are the #1-ranked commodity grown in Washington State. During 1994-1998, production averaged about 117,000,000 bushels (boxes), with an average of 88,000,000 sold as fresh and 29,000,000 processed.
- ❖ Farmgate value of Washington apples is estimated at about \$950 million yearly, with total value of the packed box and processed product sales nearing \$1.5 billion.
- ❖ From 28 to 35 percent of the crop is exported yearly, with major markets in the Asian Rim, Canada, Mexico, and South America.
- ❖ Cost to produce an acre of apples is between \$5800 and \$6600. The greatest expense is labor for picking, pruning, and hand fruit thinning. Packing and marketing costs an additional \$3,600 per acre of production.
- ❖ The average break-even price for a box of apples is about \$13.50; in 1998, growers received an average of \$10.51.

## Production Regions

The major production regions are east of the Cascade Mountains, in the north-central to south-central areas of the state. The three primary apple production regions are the Yakima Valley, with 62,000 acres, the North Central (Wenatchee) district, with 57,000 acres, and the Columbia Basin, which contains about 45,000 acres of apples. Minor production areas include the Greenbluff area north of Spokane (450 acres), and a region in the northwestern corner of the state near Mount Vernon (400 acres). Growing conditions (earliness and length of season) vary greatly across the state. Orchards in the lower Columbia Basin and lower Yakima Valley (650-850 ft. above sea level) bloom as much as three or four weeks before those at highest elevations (3000 ft.) in north-central Washington. Warmer, long-season areas are best suited to varieties such as Pink Lady and Granny Smith, while the more moderate and cooler regions are famous for their ability to produce any variety of red apple that stores well.



## Cultural Practices

### Pruning

Trees are pruned throughout the winter, while they are dormant. The orchards may be pruned any time the weather is reasonable for the pruning crews' comfort. This operation is always complete prior to the application of dormant sprays. This activity is one of the most labor intensive and expensive aspects of fruit production, as trees are not uniform, and must be pruned according to horticultural concepts. Cost of pruning is mainly for labor, and varies from about \$300 per acre on high density trellis orchards to \$500 per acre in older, large-tree orchards. Proper pruning maintains fruit quality and production over the lifetime of the orchard, and is considered the key horticultural practice.

### Irrigation

Washington apples are grown in a moderate, marine-influenced, desert climate, where scant rainfall occurs in the winter months. The dry, sunny growing-season weather gives growers the advantage of low disease pressure, but requires them to irrigate regularly. The average orchard requires about 3.5 acre feet of water per season, most of which must be applied during mid-summer, when mountain snowmelt maintains plentiful stream flows. The total of all crop irrigation in the Pacific Northwest states constitutes less than five percent of the available Columbia River Watershed water supply. Irrigation, at times, complicates pest management by triggering disease infection in specific blocks, or removing protectant materials too soon after application. Over-irrigation constitutes a leaching potential for nitrates or other easily leached products applied to the orchard.

### Tree Nutrition

The most common necessary fertilizer used in Washington apples is nitrogen (N). Overuse of nitrogen causes serious fruit quality degradation, therefore is rare. Most growers apply between 0 and 60 pounds of actual N per season, depending on appearance of the trees, fruit, and leaves. The desert soils in the region also have very little avail-

able zinc or boron. Most other major mineral nutrients are common in the soil, and specific deficiencies of potassium, copper, and phosphorus may be treated as indicated necessary by soil and foliage tests.

### Orchard Systems

Red Delicious dominates production, constituting about 46 percent of the packed crop in 2001. This figure is down from 57 percent of the crop in 1998 and 69 percent of the crop in 1990. Golden Delicious remains second in order, with 16 percent. Fuji and Gala have overtaken former third-place contender Granny Smith, with 12.9 and 9.6 percent of the crop, respectively; Granny Smith represents 9 percent. The remaining 6.5 percent is made up of Braeburn, Jonagold, Pink Lady, Red Rome, Cameo, and other varieties.

Older apple orchards are most often the Red or Golden Delicious varieties planted at about 110 trees/acre. Older trees average 18 feet wide and 14 feet high, which makes pruning, spraying, hand fruit thinning, and picking difficult and labor intensive. These trees are highly productive, and are being removed only when the varieties are no longer profitable. The rate of removal and orchard replanting has greatly increased in the 1990s, particularly in 1998 and 1999. Newer orchards are more likely to contain varieties such as Fuji, Gala, Granny Smith, Braeburn, or Cameo. Most of these new varieties are more sensitive to diseases such as powdery mildew and fire blight than the varieties they replaced. These new orchards are usually planted more intensively, on dwarfing rootstock, supported by a trellis, and planted at 600 to 1000 or more trees/acre. Production starts in the second season after planting, and full production may be attained in the fourth year of growth. "Non-bearing" labels now usually apply only to the season of planting. Trees in this intensive style of orchard are usually about 6 feet wide and 10 feet tall, which eases labor and improves spray material coverage. As sprayed product rates are usually set in relation to very large trees, growers and advisors often question how specific product rates must be adjusted to relate to the lighter foliage and superior coverage common in trellised blocks.

## **Orchard Renovation**

Orchards are replaced about every thirty to thirty-five years, as varieties become less popular, or trees are excessively damaged by severe winters. It costs at least \$15,000 to renovate an acre of orchard, including the cost of the trees, labor, fumigation, trellis and irrigation systems. Changing orchards to new varieties may lead to poor economic returns due to Specific Replanting Disease unless the soil is carefully fumigated prior to replanting. This replanting problem is especially serious in the older production regions where relatively smaller, owner-operated farms predominate. Low-acreage orchardists have much less access to commercial application of soil fumigants, and often must personally carry out the procedure. This limits their choice of fumigant products.

## **Pollination**

Apples are dependent upon pollination by honeybees for fruit set. Most apple orchards intermingle two varieties. A main variety usually predominates, making up about 66-82 percent of the planting, while a pollen-source variety fills the remainder of the space. At times, crabapples are used as pollenizers, and are not picked as a crop. One to two hives per acre provide sufficient bees for good pollination. Hives must be placed at a time when an adequate number of apple flowers are open to attract the bees; otherwise, the bees will forage for pollen elsewhere. The first open flowers, when pollinated, will produce the best fruit, as they are the biggest and will "stick" best on the tree after chemical thinning. Growers therefore prefer bees to be active in the orchard during this period. Only one good day of pollination is necessary, but due to weather conditions affecting flower opening and bee activity, hives are generally left in the orchard for four to five days. One hundred percent of apple producers contract with bee owners to provide hives. Bees are usually trucked from California to Oregon, then to Washington, then, finally, to Montana, following the cycle of blooming crops. Hives are rented at the rate of \$20-\$30/hive for one use, regardless of the number of contiguous days of that use. All growers are aware of their responsibility for bee health and of the dangers of bee poisonings and how to prevent them.

Replacement costs of hives are \$100, but the ill will generated from damage to the beekeepers' livelihood or the neighbors' pollination rate is far more expensive.

## **Growth Regulators**

Growth regulators do not affect pest pressures, but are a key component of apple production.

### ***Blossom and Fruit Thinning***

Blossom and fruit thinning is by far the most common use for growth regulators in Washington apple orchards. Fruit must be thinned every spring to assure yearly production and allow for acceptable fruit quality. If blossoms are not thinned yearly, most apple varieties will develop an alternate bearing habit, producing a heavy crop one year, then almost no crop the next. This variation in blossom set on the tree can be somewhat reduced if the great majority of blossoms and small fruit are removed from the tree during bloom, or within two or three weeks after petal fall. Chemical thinners are used during and shortly after the bloom period to prevent fruit set, or to remove fruit that may have set in clusters. Thinning the fruit by hand four to six weeks after bloom is also very common and necessary, but does nothing to ensure return bloom. The remainder of the thinning is done by hand during June and early July, with crews spending about twenty-five to forty hours of labor per acre removing poor quality, insect- or disease-damaged, or too-closely spaced fruit. Hand labor rates average \$7.50 to \$8/hour. Hand thinning serves to ensure highest fruit quality by spacing the fruit on the limb, reducing fruit clusters to singles, removing fruit that is likely to rub on the limbs, and eliminating fruit that appears damaged by early-season insects or diseases.

Blossom thinners act in two general ways: reducing fruit set by interfering with pollination (usually by damaging the flower stigma tip) or by inducing the evolution of ethylene in the fruitlet, which causes abscission (dropping off). The classic blossom thinner, DNOC (Elgitol), was taken off of the market more than a decade ago, and as a consequence Washington fruit production now varies by 10 to 15 million boxes from one season

to the next. No satisfactory blossom thinner has been developed to replace Elgitol. Products registered as replacements, such as Wilthin and Thinex have been unpredictable, even damaging fruit in some orchards. A substance with similar effect as Elgitol, Ammonium Thiosulfate (ATS), appears effective in numerous research trials. The registration process for ATS is underway.

Presently, the major fruit thinner of choice is carbaryl, an insecticide. This product is applied at 600 ppm in a full wetting spray during the period between petal fall and about fourteen days after. It may be applied more than once, if weather affects the first application. If the weather is warm (65-80°F), the weaker, smaller, and secondary cluster blossoms will drop from the tree, leaving the strongest fruit behind. Unfortunately, this product often leaves too much fruit on the tree. To enhance the activity of carbaryl, the growers often add naphthalene acetic acid (NAA), naphthaleneacetamide (NAD) and/or ethephon (Ethrel) to the thinning spray. Product mixture depends on the variety being thinned, the blossom set on the tree, and the expected temperatures during the several days following application. Advisors consider these spray decisions the most difficult of the season.

### ***Fruit Growth Regulators***

During bloom, and for the few days following, growers may apply products that enhance the growth rate of the fruitlet, somewhat enhancing fruit size and shape. The most common products applied for this purpose are a combination of gibberellic acid and benzoic acid, applied at 12.5 to 25 ppm in 100 gallons per acre.

### ***Fruit Ripening Enhancement***

To advance the development of the fruit so as to take advantage of early markets, a very small percentage of the apples are treated with ethephon (Ethrel) at 300 ppm at ten to fourteen days prior to the intended harvest date.

### ***Prevention of Fruit Drop***

To aid in the retention of fruit on the tree during the final two to four weeks prior to harvest, NAA (naphthalene acetic acid) is applied, usually by aircraft, at 0.75-1.0 ounces AI/A. To prevent

fruit drop and delay the development of "water core," a condition that greatly reduces the storability of fruit, some growers apply AVG (aminoethoxyvinylglycine hydrochloride, ReTain) at 0.73 pound AI/A.

### **Quarantine Areas**

The counties of Clallam, Clark, Cowlitz, Grays Harbor, Island, Jefferson, King, Kitsap, Klickitat, Lewis, Mason, Pacific, Pierce, Snohomish, Spokane, Skagit, Skamania, Thurston, and Wahkiakum are under apple maggot quarantine per WAC 16-470-100. The WAC also allows for the addition of other counties to the quarantine area; Whatcom County may be included in this quarantine within the next year or two. In an effort to curb the spread of this pest, fruit cannot be shipped from the affected counties, severely restricting the apple industries in those areas. None of the affected areas have local packinghouses nor storage facilities; all had depended upon shipping their apples to packinghouses in other parts of the state for storage.

### **Organic Production**

Low disease pressure from apple scab, the absence of plum curculio, and the localized occurrence of apple maggot allow Washington growers to produce apples under organic methods relatively successfully. The key pest, codling moth, prevented most growers from participating in organic production before pheromone confusion brought the pest under better control. Proper timing of summer oil sprays also helps in this regard.

In order to sell fruit labeled as organically produced, growers must be certified by an accredited organic certification entity. In Washington, most certification is conducted through the Washington State Department of Agriculture (WSDA) Organic Food Program. Applicants pay inspection fees and maintain their orchard under approved organic production methods through a three-year transition period. During this period, the transitional grower incurs the additional production costs of organic methods but does not realize the additional return that can come from organic produce because the apples cannot be marketed as organic prior to certification and the successful

completion of the three-year trial period. The transition period is therefore a financial hardship and a significant impediment to growers who might wish to try organic production.

The financial incentive for producing organic apples comes from the price premium such apples can command in the market. In practice, the price premium can range from 0% (no advantage over conventional apples) to 100% (double the price of conventional apples). The key issue is balancing return against production costs. Price fluctuation in both conventional and organic apples has been great in recent seasons. In general, market prices have decreased and international competition has increased to a point where organic producers must take a serious look at their net returns.

Most recent Washington State Department of Agriculture records (representing the 2000 growing season) show 4000 certified organic acres of apples in Washington, with another 4000 acres in transition.

### **Post-Harvest**

Roughly 108 packinghouses store, sort, box, and ship Washington apples almost all twelve months of the year. Packinghouses range in size, some capable of packing five to seven million boxes per season, others may pack as few as 300,000. Ownership may be private or cooperative, the latter with as many as 400 grower member/owners.

Successful storage is based on internal condition of the fruit. Those apples picked at the beginning of harvest ship and store best; those picked at the end of harvest, at peak ripeness, can only be held a few weeks. About 35 percent of the fruit are harvested late and kept in common storage to be sold in the fall and early winter. The remainder is stored under low-oxygen controlled atmosphere (CA), and is shipped from December until September. Most fruit is treated with a fungicide drench (thiabendazole) prior to storage to reduce fruit rots, especially those caused by *Penicillium* and *Botrytis* species. Thiabendazole is not extremely effective, and losses to fruit rots may be excessive during some storage seasons. There are no alternative products registered for post-harvest

fruit rots. Experiments utilizing newly developed biocontrol agents have not led to commercially acceptable control.

Diphenylamine (DPA) is applied with the thiabendazole drench to fruit that is susceptible to storage scald. Scald is a disorder that causes browning of the skin in storage (also called storage scald) rendering the fruit unmarketable. Organic fruit does not have any chemicals applied in storage, which decreases the marketing season by about one-half, as well as increasing losses from scald and fruit rots.

### **Pest Management**

Insects, diseases, weeds, and rodents are the most important pests of apples, generally in that order. The balance of this profile is devoted to detailing current pest management practices for Washington State apples.

## **Insects and Mites**

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### **CODLING MOTH** *Cydia pomonella*

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#### **History**

Codling moth (CM) has been the key insect pest of apples in Washington since the early 1900s. Damage was constant and, despite heavy spraying with lead arsenate, 10-25 % losses were expected



**Adult codling moth.**

Orchard Pest Management, Good Fruit Grower, Yakima, WA

yearly in orchards up until 1948, when DDT became available to growers. Control has been relatively easy since that time. Azinphos-methyl (Guthion) has been the standard control material since 1965.

For thirty years, loss of control of this insect has been considered a sign of carelessness on the part of the grower and their advisors. But since the mid-1990s, the background population of codling moth in Washington apple-growing regions has been increasing. Partial loss of control is becoming a more frequent occurrence, leading to significant economic damage rather than merely mild embarrassment. New control strategies are being adopted as growers begin to realize the older, “easy” management methods are becoming less reliable in high-pressure regions. Recent demonstration of pheromone confusion (supplemented by traditional sprays) in large contiguous blocks has reassured growers that this newly developed method works, though it remains more expensive than chemical agents.

Codling moth remains one of the more difficult pests to manage with newer, lower-toxicity control products, such as insect growth regulators, due to adult and larval behavior that differs significantly from many other Lepidoptera pests. Unlike most in this genus, the codling moth larvae do not consume leaves or fruit surface tissue. To be effective against codling moth, an insecticide must have contact action on the adult, egg, or very young larva in the few hours it remains on the foliage or fruit surface. Research shows promise of possible new control products, but none of the adequately effective materials appear to be near registration. For the next several seasons, growers may be on the brink of control breakdown while they gradually implement newer, more expensive control materials and methods.

## Life Cycle

In Washington, this insect has from two to three generations per year, depending on the warmth of the growing region and the relative warmth of the growing season. Adults first emerge about fourteen to thirty days after bloom, and first generation continues for about seven weeks, until late June. The second generation takes place during July and the first two or three weeks of August. The partial third generation may extend into early October, but damage is rare after September. Individuals from the later portion of the second generation enter diapause and overwinter in the orchard.

Males fly relatively well to find females, which generally move only a few hundred feet or less. Females attract males by releasing a pheromone. A synthetic codling moth pheromone is used in traps to detect the presence of males, and to roughly estimate the numbers of

females present in the area.

A female may lay over 100 eggs, mostly on or near fruit. Eggs hatch eight to fourteen days after they are laid. Larvae must find and enter fruit within a few hours of hatching. They enter either the skin or the calyx, and though they may chew their way into the fruit, they do not swallow the surface layer. Most newly hatched larvae fail to live long enough to penetrate fruit, however, young larvae from a single female can “sting” twenty to sixty fruit. Growers define a “sting” as surface damage to the fruit skin caused by larvae that died soon after penetrating the skin. Codling-moth-damaged fruit is discarded during sorting in the packinghouse. Once inside the fruit, the larvae remain near the surface for two to four days, then penetrate to the core, where they feed on seeds and flesh for three to four weeks. When fully grown, the larvae leave the fruit, find sheltered places on or near the host tree, and spin a cocoon. At this point, they may either remain dormant for the



**Codling moth larvae in fruit (above) and overwintering in cocoon (below).**  
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winter, or emerge after two to three weeks to further infest fruit.

The first codling moth generation is generally the smallest in number, is struggling to survive in cooler, wetter spring weather, and is easiest to contact by sprays. Successful codling moth control is dependent on proper timing of controls during the first generation. Loss of early control usually leads to greatly increased damage during the remainder of the growing season.

The development of the codling moth generations is modeled and reported by Internet (<http://www.ncw.wsu.edu/tftindx.htm> or <http://fruit.wsu.edu/>) and fax to the growers and their advisors by a cooperative program of Washington State University extension agents, advisors and technicians.

## Controls

### Chemical

**Azinphos-methyl** (Guthion). Rates range from 1 to 1.5 lbs. AI/A, usually formulated as a 50% wettable powder (WP). This product is applied by air-blast sprayer 2 to 5 times per season. The number of necessary sprays depends on the number of codling moth present in the region near and within the orchard. If the problem is mostly due to external CM sources, some applications are made to the outside forty feet of the orchard, rather than the entire block. Azinphos-methyl has been the standard control material for codling moth since the 1960s, and is applied to the great majority of apple and pear orchards. It remains the single product that may be relied on to suppress CM in high pressure situations, and is commonly required to suppress CM "hot spots" in pheromone confusion blocks. Switching to the use of this product in the mid-1960s allowed growers to eliminate the once-common use of miticides through integrated mite management. Other than the beneficial mite spe-

cies, however, this product can be relatively or highly disruptive of various beneficial arthropods. The PHI is 14 days; REI for workers likely to come into significant contact with foliage is fourteen days.

**Phosmet** (Imidan) has been available for use for many years, but has gained very little acceptance, as it is less effective than the other control materials. It has some use as a "softer material" for growers trying to avoid the use of azinphos-methyl or, now, as a replacement for methyl parathion. The term "softer material" indicates the product causes less damage to predatory mite populations critical to IPM efforts. Research has indicated it is

somewhat less disruptive of beneficial arthropods, but there is no indication that beneficials are more numerous in phosmet-treated orchards. Growers generally apply about 3 lbs. AI/A, and may use three applications per generation of CM, rather than the two applications commonly used for other products. PHI is seven days; REI is 24 hours.



**Codling moth damage on fruit.**

Orchard Pest Management, Good Fruit Grower, Yakima, WA

**Horticultural mineral oil.** Recent research has indicated that a 1% emulsion of highly refined, narrow-range boiling point horticultural mineral oil applied at a per-acre carrier rate that fully covers the tree may be effective as a codling moth suppressant. This spray is applied at 200, 400, and 600 codling moth degree-days after the first males are captured in pheromone traps.

**Esfenvalerate** (Asana) is a cheap and effective product with lower mammalian toxicity than other potential choices, but it, along with other pyrethroids, is highly disruptive of integrated mite management. Growers have wisely avoided the use of these products, as they would be forced to spray repeatedly to control the phytophagous mite complex, seriously disrupting apple orchard IPM.

## **Alternative**

**Pheromone confusion** has proven to be the most effective alternative control program in large trials and grower adoption over the past seven to eight years. Over 45,000 acres of Washington apples were treated with pheromone emitters during the 1998 growing season and 65,000 acres in 1999. Growers apply 160 to 400 pheromone-releasing devices per acre each season just prior to the flight of the first males. Pheromones in the orchard air make it very difficult for males to find and mate with females. Problems arise near the edges of the treated block, where pheromone coverage is less consistent and some successful location and mating can take place. Also females that have mated outside treatment boundaries may enter. Due to these “edge effects,” most successful pheromone treatments have been over very large acreages. Isolated or large treatment areas have had a history of successful control, with codling moth populations dropping to historic lows within the treated area. Control is not perfect, however, and chemical sprays are often used as a supplement throughout the first season and to control outbreaks thereafter. As the pheromone treatment materials are initially more expensive than more traditional control methods, growers are reluctant to initiate this program during the recent difficult economic situation. Some growers who have had initial success have dropped the use of this product due to its expense. In orchards with historically difficult-to-control codling moth populations, or those orchards irrigated by over-tree sprinklers, the combination of pheromone confusion and supplemental sprays has been more effective and economical than the alternatives.

The most common commercial pheromone emitter is the Isomate C++, which has proven most reliable and longest lasting of the available products. The only other commercially accepted product at this time is the Checkmate CM emitter. Numerous other emitters are being tested.

**Sterile moth release:** British Columbia fruit growers have supported a very large program of sterile codling moth release for the past seven seasons. This has proven to be very expensive (about \$200 per acre per year) and not as successful as early pilot projects had indicated. A great amount

of Canadian Government, non-orchard landowner and grower support has been required to initiate and carry out the program. A cooperative project of sterile moth release in a large (1000 acres) pheromone confusion project immediately south of the USA-Canada border has proven quite successful, though impractical on a wider scale.

## **Cultural**

Orchards are designed and trees pruned to greatly improve spray application efficiency. Growers stack orchard props or fruit bins contaminated with overwintering codling moth larvae well away from orchards when possible.

## **Biological**

Few biocontrol agents for this pest presently exist in Washington. *Trichogramma minutum*, a small wasp that lays its eggs inside the codling moth egg, is sold as a biocontrol agent, but is effective only in reducing the percentage of damage in very highly infested orchards. Efforts to identify effective predators and parasites continue in regions where apples are native, with the idea of transplanting them into apple production regions.

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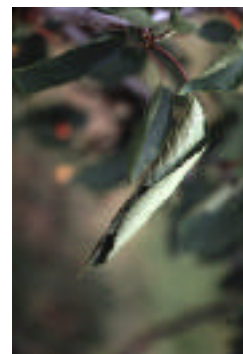
## LEAFROLLERS

**Pandemis Leafroller, *Pandemis pyrusana* Kearfott**  
**Obliquebanded Leafroller, *Choristoneura rosaceana* (Harris)**

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## **History**

Pandemis leafroller has been a common but easily controlled potential problem in the Wenatchee and upper Yakima Valley districts for thirty or more years. However, both this pest and obliquebanded leafroller have increased their range and importance to become the most damaging secondary pests in the state. It is likely that both were controlled by



**Leafrollers are so named because the larvae tend to roll leaves like this.**

Orchard Pest Management,  
Good Fruit Grower, Yakima

routine codling moth programs until they became resistant to the usual sprays.

## Life Cycle

Small larvae overwinter on the tree and become active as the foliage and flower buds develop. They feed in the foliage, flowers, and young fruit until late May and early June, pupate on the tree, and emerge as adults in mid-June through early July.

Larvae from this generation feed high in the tree on the young leaves of the shoot terminals. As they gain size, they may migrate into the tree interior and damage the developing fruit. A second summer generation will often develop during the month prior to harvest, damaging the near-mature fruit with “pin-hole” feeding wounds. Control of this pest is most certain if effective materials are well timed during good weather in the pre-bloom period. Unfortunately, the weather conditions are not often optimum, and leafrollers remain on the trees into the summer. Males fly relatively long distances from native tree hosts, so trap catches do not illustrate the number of females that may exist in the orchard. Growers and advisors find it very difficult to monitor this insect, and control thresholds are not established, despite a substantial research effort. Control procedures are usually carried out based on the history of problems in the block, rather than observed damage. Management methods and materials are being researched. Until these tools are developed, this pest will remain one of the most difficult to manage with any degree of certainty.

## Controls

### Chemical

**Spinosad** (Success2L) is recommended at 6-10 ounces product/A (0.09 – 0.16 lbs. AI/A), and with 0.25% horticultural mineral oil added to the spray mixture. This product is quite effective, and has the additional benefit of being “softer” on ben-

eficial arthropods and relatively easy to use around foliage contacting orchard laborers. It is narrow in its spectrum of activity, and will not control scales, aphids, and *Campyloomma*, as alternative products will.

**Chlorpyrifos** (Lorsban) is used at 2 to 2.5 lbs. AI/A. It is most often applied in combination with 1.5-2.0% (1.5 to 2 gallons of oil/100 gallons of spray mixture) horticultural oil, pre-bloom, on new leaf and flower bud tissue, while overwintering larvae are foraging actively. At this tim-

ing, this product combination is effective in suppressing red mites, San Jose scale, aphids, *Campyloomma*, and leafrollers. This product remains the most useful chemical control for leafrollers.

***Bacillus thuringiensis*** (Bt) is an organism toxic to insects in the Lepidoptera family if ingested in relatively large amounts. Sublethal exposure tends to retard the development of the treated individuals, but does not seem to reduce the damage they cause or their ability to reproduce. If applied during relatively warm temperatures, when larvae are feeding actively, control is quite satisfactory. The product has no impact on beneficial arthropods, and kills only those Lepidoptera that are in the larval stage and feeding directly on treated foliage. Growers apply Bt pre-bloom, at petal-fall and during the larval stage of the first summer generation, which usually occurs in June.

### Cultural

Orchards are designed and trees pruned to greatly improve spray application efficiency.

### Biological

A great number of predators, parasites, and other beneficial organisms play a part in suppressing these pests. At times, this complex suppresses leafrollers in small blocks very well, especially later in the growing season. Unfortunately, under present management conditions, this biocontrol is



**Pandemis leafroller (left) and obliquebanded leafroller (right), both in mature larval stage.**

Orchard Pest Management, Good Fruit Grower, Yakima, WA

not at all dependable, and direct damage to the fruit is very common unless larvae are artificially suppressed.

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## SAN JOSE SCALE

*Quadraspidiotus perniciosus* (Comstock)

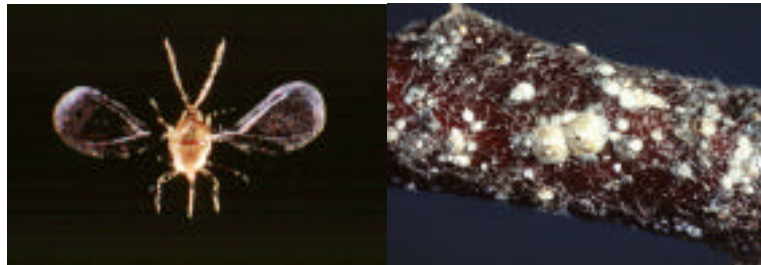
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### History

San Jose scale is an introduced pest that has been a potentially serious problem in Washington orchards for almost 100 years. It has a wide host range, attacking not only all tree fruits, but also a number of related native hosts. It is most troublesome in older orchards where spray coverage is difficult and in orchards that are near ornamental or native hosts that maintain uncontrolled populations. Large populations of this pest can seriously injure the tree, and even small populations may attack and cull high percentages of the fruit.

### Life Cycle

Scales overwinter on the tree and mature in the early spring. Males emerge from under their scale and mate with the females, which remain under their protective covering. Each female then produces several hundred live young (crawlers) over a six-week period. These crawlers disperse onto the twigs and fruit during June and July. These crawlers settle, develop a waxy scale cover, and feed by sucking sap from the tree. They mature, and produce a second generation of crawlers, often in much higher numbers than the first generation, during August through October. These scale often move onto the fruit. One scale can cause a fruit to be discarded during the packing process, and presence of scale is often considered a quarantine violation in international trade.



Adult male San Jose scale (left). Scale damage on branch (right).

Orchard Pest Management, Good Fruit Grower, Yakima, WA

### Controls

#### Chemical

**Horticultural mineral oils** (numerous brand names) are the most important control materials. They are usually applied in the early spring, shortly after the tree has commenced growth, but prior to blooming, after the overwintering scale have broken their dormancy. The infested trees are usually sprayed with a 1.5 to 2 percent suspension of oil in water carrier per acre adequate to fully cover the tree, even behind bark scales, crevices, pruning stubs, and other hard-to-contact areas of the tree. The volume of water/pesticide mix varies from 60 to 400 gallons per acre, depending on tree size, usually about 200 gallons/acre. In almost all instances, the oil is mixed with an insecticide to improve the percentage control. This mixture is much more effective

than either component alone. This oil-insecticide mixture is also a very important part of the integrated mite management process.

**Chlorpyrifos** (Lorsban) is commonly used, as it affects multiple important pests (including leafrollers and *Campylopus*) when used in early spring with oil. The emulsifiable concentrate formulation is usually applied at this time, as it is more practical to mix with horticultural oils. Rate recommended is 1 pint (0.5 lb. AI) per 100 gallons of water carrier. The WP formulation of this product is sometimes used during the summer to control the crawler stage, if spring oil application was not entirely effective.

**Azinphos-methyl, carbaryl, and phosmet**, when used to control other pests, may suppress, but will not control, the summer crawler phase of this pest.

**Diazinon** (Diazinon) is recommended, but seldom used, as it has much less effect on other pests that may be present at the time of application.

### Alternative

Organic growers often spray with a fish oil emulsion in the spring instead of horticultural mineral oil. The fish oil is very limited in supply, inconsistent in quality, and expensive.

### Cultural

Planting orchards on size-controlling rootstocks and pruning to keep trees in an open habit to improve spray coverage are the most effective cultural control practices. Small, young, well-sprayed trees rarely have San Jose scale problems.

### Biological

Some natural predators and parasites attack, but do not control, this pest. Biological control is only supplemental to chemical control.

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## TRUE BUGS

Lygus Bug, *Lygus lineolaris* (Beauvois)

Conspers Stink Bug, *Euschistus conspersus* (Uhler)

Green Stink Bug, *Acrosternum hilare* (Say)

Western Boxelder Bug, *Leptocoris rubrolineatus* (Barber)

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### History

These insects in the “true bug” family feed directly on fruit. They are a sporadic but especially difficult pest complex that has been an increasing problem in Washington orchards near forest or brushy non-crop land. Some orchards have sustained 100% damage in the rows adjacent to brush land, and bug-feeding damage has become the most common insect-caused cullage in some regions.

### Life Cycle

This group of true bugs usually overwinters as adults, and has one or two generations during the spring through late summer. They live primarily on native plant species in native brush land outside of the orchard, and fly into the orchard as adults when their

native hosts begin to dry and lose their fruits or other feeding sites. The adults damage the ripening apples by piercing the skin with their beaks and sucking fluids from the flesh during the four to six weeks prior to harvest. Damage appears as shallow, circular, light brown to white spongy pockets in the fruit flesh, usually from 5-10 mm in circumference, and 5-8 mm in depth. The damage is often mistaken for “bitter pit,” a calcium-deficiency disorder. Typical feeding damage tends to be on the stem end or sides of the fruit, as those parts of the fruit surface are easier for the insect to stand on, and most likely to be covered by foliage, providing protection to the feeding bug.

Assessment of true bug population levels in the orchard is very difficult, and thresholds are not easy to establish. There is no effective trap for most bugs, and sweep nets or beating trays are not practical on trees with full-sized fruit. The bugs have good eyesight, and move out of view if they see movement. The opinion of most pest scouts is “if you see a few, many more are likely there.”

Since this group of bugs matures outside of the orchard, growers have little opportunity to control them during their nymph stages, when they are more vulnerable to sprays. Research has not yet developed a reliable trap to monitor populations in the non-crop land around orchards. There is some hope that adult bugs may be attracted by aggregation pheromones or by “trap crops” that are more attractive to the population than the ripening apples, then killed by relatively inexpensive insecticides outside of the orchard. This process is being researched, and has not yet been demonstrated to be effective. Most control requires repeated applications of insecticide, espe-



Apples damaged by early *Lygus* feeding (left). Adult *Lygus* bug (above).

Orchard Pest Management, Good Fruit Grower, Yakima, WA

cially along the borders of orchards, during the period of adult in-flight.

## Controls

### Chemical

**Formetanate hydrochloride** (Carzol 92SP) is, by far, the most commonly used product for the control of all true bug pests (24c, WA-000028). It is effective at about 1 pound of the 92% AI product per acre, and is popular because it may be applied within 16 days of harvest. The short pre-harvest interval is important, as this is the period when most of the true-bug damage occurs. Applications seem to be effective by contact only, and must be repeated when the orchard is re-infested.

**Endosulfan** (Thiodan 50WP) is the only other product that provides adequate control of true bugs (24c, WA-780033). It is applied at 2.0-2.5 lbs. AI/A, usually only once a season, as the pre-harvest interval is 21 days.

**Esfenvalerate** (Asana) is an effective product, and is applied to the rangeland closely bordering orchards in the effort to control the bug population prior to their movement into the orchard. The product is **not** used in the orchard, as it is highly disruptive to the normal biological control of mites.

### Cultural

Some growers have attempted to remove host plants from the brush lands bordering the orchard, in the effort to reduce the build-up of the bug population during the spring and summer. This approach has had some very limited effect, but has not yet provided adequate control.

### Biological

Bugs have many predators, parasites, and parasitoids, but seem to withstand them well. There are variations in the numbers of bugs moving into orchards from one season to another, and it is possible that weather and biological factors influence these variations.

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## MULLEIN PLANT BUG

*Campylomma verbasci* (Meyer)

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### Life Cycle

This is also a true bug, but is separated from the others for two reasons: (1) its life cycle is carried out mostly within the orchard and nearby, and (2) it is a pest only during a short period of fruit development, then becomes a beneficial predator of soft-bodied pest insects for the remainder of the season.

Mullein plant bug overwinters as an egg inserted under the young, green bark of apple trees. Because of this, it is not easily affected by oil and insecticide sprays applied prior to emergence. The young hatch and emerge over a few days sometime during the pink to petal-fall stages on the apple tree. Emergence time varies from year to year, and has not yet been temperature modeled. Damage is caused when the nymphs feed directly on the fruit, instead of aphids, the latter being their more usual food source. Fruit damage is sporadic, both from orchard to orchard and from year to year. Sudden outbreaks and unacceptable damage to some sensitive apple varieties sometimes surprise growers who believe they have found a “soft” alternative for spraying this insect. This uncertainty greatly complicates management. Growers and advisors must monitor extensively and frequently to observe the hatch soon after it begins, and assess whether the numbers caught on beating trays exceed known thresholds for the infested fruit variety. Damage usually occurs over a matter of five to ten days during bloom and shortly thereafter. Most effective control timing is usually full pink through full bloom. Petal-fall is almost always too late to prevent significant damage. Growers need a product that can be applied during bloom and is effective, yet safe for honeybees.

*continued next page*

## Controls

### Chemical

**Formetanate hydrochloride** (Carzol 92SP) is, by far, the most commonly used product for the control of this pest (24c, WA-000028). It is effective at about 1 pound of the 92% AI product per acre, and is used most commonly because if applied in the evening, it is acceptably safe to bees and other pollinating insects. Applications seem to be effective by contact only.

**Chlorpyrifos** (Lorsban) is commonly used in the late pink stage of tree development, as it has effect on multiple important pests (including leafrollers and San Jose scale) when used at this time with oil. Other pests are also controlled. The emulsifiable concentrate (EC) formulation is usually applied, as it is more practical to mix with horticultural oils. Rate recommended is 1 pint (0.5 lb. AI) per 100 gallons of water carrier.

### Cultural

Growers and fieldmen report that the presence of aphids during bloom reduces the on-fruit feeding of the *Campylomma* nymphs. As higher numbers of aphids present on the tree during bloom also leads to fruit damage, this relationship between one pest and another is a delicate balance to maintain. Some fruit varieties, such as Fuji and Red Delicious, are more tolerant of *Campylomma* presence than others, such as Gala and Golden Delicious.

### Biological

Few if any significant biological control agents have been identified. It appears this insect causes damage more often in orchards where broad-spectrum insecticides are sprayed during the late spring, but this may be a secondary effect.

### Other Issues

Careful monitoring of the pest during the bloom period can greatly reduce the amount of spraying required for control, while decreasing the overall amount of fruit damage. Unfortunately, there are not enough field advisors to carry out this service on a near-daily basis in multiple sites on

every orchard. Growers are very busy with multiple insect and crop decisions during apple bloom, and are unlikely to stay vigilant every season to catch the insect during the one year out of 8 or 10 that it is likely to exceed thresholds and cause significant crop loss. There is a wide gap between what we know and what we can do about this pest.

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## TETRANYCHID MITES

European Red Mite, *Panonychus ulmi* (Koch)

Two-Spotted Spider Mite,

*Tetranychus urticae* (Koch)

McDaniel Mite,

*Tetranychus mcdanieli* (McGregor)

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### History

The European red mite is the most common and serious mite that attacks apple in Washington. It was introduced into the state in the early 1900s, and caused significant damage until the 1960s. It is currently present in most orchards, and causes sporadic damage when biological control is disrupted.

The two-spotted spider mite (TSM) and McDaniel mite have very similar life histories and modes of action. Both have a relatively wide host range, especially the TSM. While TSM is recognized as a pest worldwide, the McDaniel mite is a problem mainly in the Pacific Northwest. Except in hot, dusty orchards, the McDaniel mite is the more common of the two on Washington State apples. Neither commonly cause problems in apples unless biological control is disrupted.

### Life Cycle

The European red mite overwinters in the egg stage, on the tree. Eggs are deposited in the fall on the twigs and buds of the host tree. Egg hatch begins as the host tree begins to grow in the spring, and is completed in about seven to ten days. The larvae feed on the emerging leaf and flower tissue, preferring the undersides of the oldest leaves. The mites develop through two more nymph stages, and mature into adults starting about petal fall. The females begin to lay eggs within about two

days of maturation, and can lay about thirty to thirty-five eggs during their two- to three-week lifetimes. Eggs are deposited on both sides of leaves, concentrated near the midrib and larger veins. The red mite can complete five to seven generations per summer, depending on average temperatures. Each generation can be completed in ten to twenty-five days. When weather conditions warm in early summer, populations can develop rapidly. When numbers are high, the mites can spread downwind by “ballooning” on silken webbing. Starting in August and continuing into September, overwintering eggs are deposited on the woody parts of the tree. When populations are high, egg deposition inside the calyx end of fruit is common.

TSM and McDaniel mite overwinter as females in leaf litter near the base of the tree and, more rarely, in sheltered sites under bark scales. They emerge in the spring around the half-inch green stage of the apple, and move onto weed hosts or into the lower, inside portions of the tree, laying eggs and feeding on the undersides of newly expanded leaves. The overwintering females can lay about forty eggs during their twenty-one-day active period. This relatively slow egg-laying rate and the low numbers of overwintering adults leads to relatively successful biological control by the western predatory mite during the early growing stages. Numbers of two-spotted and McDaniel mites increase rapidly on the tree only if populations are not held in check by predators, leaf surfaces become dusty, or high populations build on excessive weed growth, then move up into the tree after the weeds are killed by herbicides. During warm summer months, the females can lay about 100 eggs during their thirty-day lifetime, which greatly increases potential for population flare-ups. Generations may take as few as ten days to complete during warm weather, and begin to overlap throughout the summer and fall. When weather cools in the fall, the orange overwintering females begin to form and migrate down the tree. If populations are very high, clusters of these females may form on the lower ends of fruit, spinning heavy mats of webbing over the calyx.

## Controls

### *Integrated Pest Management (IPM)*

Control of all mites on apples depends mainly on the maintenance of predators. Dormant oil is used in most blocks as an additional means to manage European red mites. Miticides are used only when damage threatens to become economic.

Dormant oil plus an insecticide is applied as trees break dormancy in the spring. This combination is aimed at control of San Jose scale and the eggs of European red mites. The oil smothers the red mite eggs, greatly reducing their survival. On the other hand, the oil does not control the apple rust mite (*Aculus schlechtendali* Nalepa), which is not considered a pest on most apples, unless their numbers are excessive. These rust mites serve as a food source for the western predatory mite (*Typhlodromus occidentalis* Nesbit), which overwinters in the leaf litter under the tree, and move into the tree during bloom and shortly after. The predatory mite population increases with this plentiful food supply, and is numerous when the weather warms and red, two-spotted, and McDaniel mite populations begin to build. The keys to this program are to (1) reduce red mite populations early with dormant oil; (2) maintain rust mites as a food source for predators; and, (3) do not kill the predator mites with the application of inappropriate insecticides or excessive rates of products that may otherwise be safe to predators. This program of biological mite control was initiated in the 1960s and is the standard in most Washington apple orchards.

In the 1960s and 70s, many products killed predators when applied to orchards. Since the 1980s, predator mites seem to have developed a variable degree of resistance to commonly sprayed products in many orchards. The use of most pyrethroid insecticides or the carbamate insecticide methomyl (Lannate) will currently disrupt mite control in most orchards, but higher rates of carbaryl or azinphos-methyl rarely cause problems. Since the 1960s, growers have been advised to use only those products and rates that will maintain mite predators in the orchard. The more common

biocontrol disruption occurs following the over-control of rust mites in the early spring caused by repeated use of sulfur-containing materials, endosulfan, carbaryl, and formetanate hydrochloride. None of these products used singly cause undue mite flare-ups, but when used in series may leave the trees relatively free of rust mites.

### **Chemical**

**Horticultural mineral oil**, mixed at about 1.5 to 2 percent by volume in water, is applied at a volume that fully wets the tree surface (including sheltered areas) during the “delayed dormant” growth stage in late winter or early spring. Mineral oils of lighter weight are sometimes applied during summer months to control excessive mite populations. In summer, about one percent oil by volume is more commonly used.

**Fenbutatin-oxide** (Vendex 50WP) may be used in summer at 0.75-1.0 lbs. AI/A.

**Pyridaben** (Pyramite 60WP) can be applied at 2.64 to 5.28 ounces/acre. Lower to moderate rates are effective on European red mites, moderate to higher rates are necessary for control of McDaniel and two-spotted mites.

### **Cultural**

Growers pave or oil roads in or adjacent to orchards in an effort to decrease the amount of dust on the trees. Over-tree irrigation seems to greatly reduce mite population and damage. Younger trees are more easily sprayed, leading to more effective red mite control. Controlling weeds in the fall, rather than late spring, greatly reduces the migration of two-spotted mites into the trees.

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## **APHIDS**

**Green Apple Aphid, *Aphis pomi* (De Geer)**

**Spirea Aphid, *Aphis spireacola* (Patch)**

**Apple Grain Aphid,**

***Rhopalosiphum fitchii* (Sanderson)**

**Woolly Apple Aphid,**

***Eriosoma lanigerum* (Hausman)**

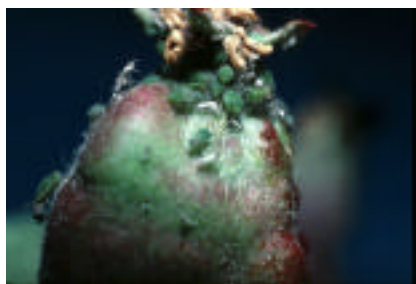
**Rosy Apple Aphid,**

***Dysaphis plantaginea* (Passerini)**

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**History.** Aphids are sporadic pests of apples, but can cause significant economic losses in some orchards almost every season if not controlled. Young, vigorously growing trees may develop high populations on portions of the tree that are developing into long-term structural wood, possibly reducing the value of that tree in its developmental years. Apple, grain, and rosy aphids may at times do direct damage to fruit, but most damage occurs when high populations drip honeydew (excrement) on the fruit, leading to russet of the skin and growth of black sooty-mold fungus. Aphid feeding causes little damage to the mature tree, with the exception of the marked growth and fruit deformation that results from the toxins injected by the rosy apple aphid. Aphids are very often attacked by beneficial insects, but usually after the damage has been done to the fruit or tree. The most common aphids in Washington are the green apple and spirea aphids, two species distinguishable only by skilled entomologists.

continued next page



**Several of the aphid species known to be pests of Washington apples. From left: apple aphid, rosy apple aphid, and woolly apple aphid.**

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## Life Cycle

All of the aphids listed, except the woolly, overwinter on the tree as eggs. The eggs hatch in the very early spring as the tree breaks dormancy. A mixture of species may be on the trees simultaneously. During bloom, direct damage to the fruit may occur if high populations of aphids feed on the flowers and very young fruit. As the season progresses, colonies may become quite numerous and may attack the young shoot tips. Apple grain aphids leave the tree as winged adults in their second generation, therefore their population declines by late spring. The other species have eight to ten generations per season, producing winged forms throughout the season that can spread to other apple trees. As the host trees' growth slows in mid-summer, and shoot tips stop growing, the aphid colonies lose their primary feeding sites. The loss of feeding sites and the build-up of multiple species of predators and parasites usually reduce aphids to below damage thresholds. But by this time, fruit may already be damaged.

Woolly apple aphids have a life history that differs significantly from those described above. They are native to North America, and may be found on native tree hosts near the orchard. Woolly aphids may live on the aboveground surface of the tree or on the roots. If roots are heavily infested, which is rare in Washington, the tree growth may be stunted. Colonies form above the soil in mid- to late summer on the bark of twigs, or on the young, actively growing edges of pruning wounds. There is no egg stage of this aphid in Washington apple orchards. They overwinter as a young nymph on the roots of the host trees. In the spring, the overwintering aphids mature, then produce wingless young, which migrate up the tree and re-infest the aboveground portions of the tree. If colony numbers remain high due to poor biological control or lack of effective sprays, excessive honeydew may damage the fruit. Both aphids and their predators seem to be more active after mild winters. Serious outbreaks of this aphid are rare, as they are controlled by sprays aimed at other pests, or by a wide range of natural enemies. When necessary, sprays are usually applied in mid-summer.

Woolly apple aphids' feeding on canker and wound edges plays an important role in the yearly re-infection of the tree by the canker and fruit rotting fungus *Neofabraea malicorticis*, the causal agent of bulls-eye rot.

## Controls

### Chemical

Chemical control options are limited and often have marginal effect on the target insect. Where aphids have developed resistance, chemical applications may do more harm than good by removing natural enemies of the aphid. Dormant-oil-plus-insecticide combinations can greatly reduce overwintering aphid egg populations, but must be well timed and carefully applied to have moderate control effect. Dormant oils without insecticide do not provide adequate control.

**Imidacloprid** (Provado 1.6F) is the only aphicide currently available that is generally effective at controlling most aphid species. The use rate is 1-2 fluid ounces of product / 100 gallons of water, applied to fully wet the tree, or 4-8 fluid ounces per acre (0.05-0.10 lbs. AI/A). The most common rate used is 5 fl. ounces per acre. The addition of 0.25% by volume horticultural mineral oil to this spray greatly enhances the effect.

**Endosulfan** (Thiodan 50WP) is considered by most growers and advisors to be the only product that provides reasonable control of woolly apple aphid, but it has almost no effect on other aphid species (24c, WA-780033). It is applied at 2.0-2.5 lbs. AI/A, usually only once a season, as the pre-harvest interval is 21 days.

**Dimethoate**, **Diazinon** and **M-pede** are registered and recommended, but are ineffective in most commercial orchards.

**Esfenvalerate** (Asana) is registered, but not recommended, as it would greatly disrupt biological control of mites.

### Cultural

Trees may be grown at a lower vigor level, a difficult balance between continued productivity of the tree, fruit quality, and reduced pest pressure. Low-vigor trees are more likely to set lighter crops

on alternate years, and trees with lighter fruit set grow more vigorously, which defeats the purpose of growing the tree in a low state of vigor.

### **Biological**

Lacewings, snakeflies, lady bird beetles, syrphid and other predaceous flies, earwigs, wasps, and numerous other insects all feed on aphids and play an important role in keeping their numbers in check. Augmentative releases have been tried, but in general are not successful. Growers simply try not to discourage natural populations. Some seasons they are numerous enough to maintain aphid populations below fruit-damaging thresholds in the spring and early summer. Other years, they are not.

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## **WESTERN TENTIFORM LEAFMINER** *Phyllonorycter elmaella* (Doganlar)

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### **History**

This insect was introduced into the Pacific Northwest in the late 1970s and spread throughout the apple production region during the 1980s and 90s. It can be found in all areas now. Its primary predator, the wasp *Pnigalio flavipes* (Ashmead) tended to spread with the leafminer across the state, but did not build up to adequate levels until two or three years after the pest had entered a new region. Most areas of the production region have had a two or three year period when leaf damage due to this insect reached unacceptable levels in a high percentage of orchards. After the *Pnigalio* wasp built up in each region, outbreaks of this pest have been much less common. Almost every year, this pest will flare up in some orchards and may require control. The population of this insect is sometimes high early in the season, but does not develop excessively during the summer and fall. If predators are present, and not killed by poorly timed sprays during April and June, they will usually control the leafminers naturally. Most advisors understand the threshold relationship between numbers of leafminers and their predator, and take care to preserve the *Pnigalio* in the orchard.

### **Life Cycle**

Leafminer damages trees primarily through damage to leaves, thereby indirectly affecting tree vigor. Direct effects of leaf damage include opening up the tree canopy, resulting in sunburned fruit. Sprays applied during the first adult flight (pink stage on the tree) were once popular, as the adult is quite visible at this time. The more difficult, but more effective, time to assess leafminer populations and the level of predator activity is in June, as adults are emerging for the second generation. If numbers of adults emerging appears quite high, and few predator pupae are found in the mines of first generation larvae, a control spray may be applied prior to the advanced development (tissue feeding) of second-generation mines. Sprays need not control all leafminers, as some individuals must remain to allow the build-up of the predator.

### **Controls**

#### **Chemical**

**Spinosad** (Success 2L) is quite effective, and has the additional benefit of being “softer” on beneficial arthropods, and relatively easy to use around foliage contacting orchard laborers. It is narrow in its spectrum of activity, and will not control scales, aphids, and *Campylomma*, as alternative products will. It is recommended at 6-10 ounces product/acre, and with 0.25% horticultural mineral oil added to the spray mixture.

**Abamectin** (Agri-Mek 0.15 EC) is recommended at 10 fluid ounces product per acre (0.09 – 0.16 lbs. AI/A), with 0.25% horticultural oil in the spray volume, at the timing between emergence of the second generation adults and the development of tissue feeding larvae.

**Malathion/Methoxychlor** (mixture, 2 lbs./gallon of each active ingredient.) This mixture is applied at 2 quarts product per acre (1 lb. AI/A each active ingredient) at the time of peak second-generation adult flight. This spray suppresses, but does not completely control the adult population. As adult leafminers emerge prior to emergence of the *Pnigalio* adults (see *Life Cycle*, above), the spray does not contact the beneficial insect, so most of the predators remain in the orchard to suppress

escaped leafminers for the remainder of the growing season.

**Oxamyl** (Vydate 2L) was the first insecticide found to be effective at controlling this pest inside the leaf. It is applied at 1-2 pints product per acre (0.25-0.5 lbs. AI/A) in 100-200 gallons of water carrier. This product is used much less now than when the pest first swept across the state, as it is somewhat disruptive of biological mite control, and red mites sometimes flare up the spring subsequent to its use.

### **Biological**

Biological control is the rule in most orchards, most seasons. Intervention is necessary only when the *Pnigalio flavipes* population is inadvertently killed, or drops to very low numbers due to a lack of hosts. There are few alternate hosts for the *P. flavipes* in native plants, and none within the orchard. This leads to a natural variation in the numbers of predators present, which may result in minor outbreaks that approach significant numbers in about ten percent of the orchards about every three to five seasons. Careful timing of sprays aimed at the suppression of other pests, and sprays that leave low populations of leafminers in the orchard maintain the biological control of this insect.

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## **WESTERN FLOWER THRIPS** *Frankliniella occidentalis* (Pergande)

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### **Life Cycle**

Western flower thrips are very commonly found in Washington orchards, but cause economic damage only to sensitive varieties, such as Granny Smith. Most common damage results from egg deposition and the resulting “pansy spot” marking of the skin. This damage is visible mainly on dark-green-skinned varieties. Rarely, adult feeding on the flowers and very young fruitlets may lead to scarring and russetting; impacted fruit must be culled. This thrip has a wide host range both within and outside of the orchard. After overwintering in ground cover, the adults emerge in

early spring to feed on many flowering plants. Eggs are deposited in leaves or in fruit if leaves are sparse. If adult numbers are high, weather is warm, and flowering hosts are few at the time of fruit-tree flowering, damage may occur at economic levels. It is very difficult to monitor this insect and respond to thresholds, as the pest is sporadic and correlation between observed numbers and actual fruit damage is poor. In orchards with a history of thrips damage, thrips are monitored during the pink through petal-fall period. If thrips adults exceed one adult per flower cluster, sprays are advised. Under higher pressures, and if adults are migrating into the orchard, more than one application may be necessary.

### **Controls**

#### **Chemical**

**Formetanate hydrochloride** (Carzol 92SP) is, by far, the most commonly used product for the control of this pest (24c, WA-000028). It is effective at about 1 pound of the 92% AI product per acre, and is used most commonly because it is acceptably safe to bees and other pollinating insects if applied in the evening. Applications seem to be effective by contact only.

#### **Biological**

Lacewings and adults and nymphs of predatory bug species feed on immature thrips. Biological control is the rule in most orchards, most seasons. Sprays are applied only when biological control is not adequate to prevent economical damage.

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## **WHITE APPLE LEAFHOPPER** *Typhlocyba pomaria* (McAtee)

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### **Life Cycle**

This insect is native to North America, and was not considered a significant pest in Washington apple orchards until the 1970s. At that time, it apparently became resistant to some of the more commonly applied organophosphate insecticides,

such as azinphos-methyl. Eggs are inserted under the young, green bark of apple trees in the fall. The eggs begin hatching during late winter, and, by about petal-fall, most of the eggs have hatched. Adults begin to fly by late May; they lay eggs over an extended period during the summer. The second generation emerges over an extended period, generally building in numbers as harvest approaches. The nymphs and adults feed on the underside of leaves, and, when numbers are high, can greatly reduce the viability of the more seriously damaged foliage. Research has not been able to document an economic loss following heavy feeding damage. The population of this insect can build to very high levels in some orchards by harvest time, and the adults fly when disturbed by pickers, often into workers' eyes, noses, and ears. This may sound inconsequential to those who have not experienced the problem, but pickers often refuse to continue working in highly infested orchards, and disrupted harvest schedules may lead to economic loss. Most leafhopper control is carried out to prevent worker discomfort, and is considered a key pre-harvest consideration in infested orchards.

Sprays applied during the summer may control only a small percentage of the active generation. Most effective spray timing is around the petal-fall period, as most of the leafhoppers are hatched and concentrated in the more susceptible nymph stage. It is difficult for most growers to spray their orchards pre-harvest, as fruited limbs block access. Aerial application of insecticides has not proven effective in controlling this pest, so growers are often advised to control the first generation if leafhoppers are expected to be a problem.

## Controls

### Chemical

**Carbaryl** (numerous brands and formulations) is applied at 1 pound AI/acre, most commonly as a fruit thinning spray, incidentally controlling the pest, or pre-harvest at approximately one week prior to harvest.

**Imidacloprid** (Provado 1.6F) is used at the rate of 1-2 fluid ounces of product/100 gallons of water, applied to fully wet the tree, or 4-8 fluid ounces per acre (0.05-0.10 lbs./A). The most common rate used is 5 fl. ounces per acre. The addition of 0.25% by volume horticultural mineral oil to this spray greatly enhances the effect. Imidacloprid and carbaryl are the two most commonly applied products at pre-harvest for control of this pest.

**Endosulfan** (Thiodan 50WP) is applied at 2.0-2.5 lbs. AI/A, usually only once a season, at petal fall, as the pre-harvest interval is 21 days.

**Formetanate hydrochloride** (Carzol 92SP) is applied at the rate of 1 pound of the 92% AI product per acre, usually during petal fall (24c, WA-000028).

## Other Considerations

Leafhoppers are often controlled inadvertently by application of carbaryl being used as a fruit thinner during the petal-fall period. If this product were no longer used as a fruit thinner, leafhoppers would likely appear in higher numbers in orchards that had not previously had the problem.

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## SHOTHOLE BORER *Scolytus rugulosus* (Muller) and AMBROSIA BEETLE *Xyleborus dispar* (Fabricius)

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These insects are the major fruit-tree-bark beetles in Washington orchards. They cause far more damage in stone fruit orchards than apple or pear, but can be found in any fruit species. Infested orchards can be economically damaged before the grower notices the "shotholing" signs of insects' presence. Both shothole borers and ambrosia beetles can cause significant tree damage every season in orchards near native-tree habitat. Otherwise, they are sporadic pests that may build up in winter-injured trees or pruning-wood piles, then spread locally, damaging more healthy trees in the neighborhood.

## Life Cycle

The shothole borer, the more common of the two insects, overwinters as a pupa in burrows formed under the bark the previous season. They develop into adults in the early spring and emerge to feed on tree twigs and leaves, then burrow into the bark to lay about fifty eggs inside long, narrow galleries. These eggs hatch, and hatchlings burrow at right angles away from the mother's gallery. This burrowing does extensive damage to the interface between bark and wood, and may kill the tree or major limbs if damage causes girdling. The larvae pupate, then emerge in May and June, when the cycle is repeated, often with higher adult numbers. This generation remains inside the bark to emerge the next spring, or may emerge for a second summer generation, causing damage in September and October.

Ambrosia beetles overwinter as adults, and do not become active until daytime temperatures exceed 65°F, usually around blossom time. Females seek weaker trees or limbs, and bore into the wood, where they lay about fifty eggs in short side galleries. The female tends the larvae, feeding them a cultivated fungus from the main gallery during their development. The young pupate, then develop into adults that remain inside the gallery until the next spring.

Control of these pests is made difficult by the long periods they spend under the bark, and their protracted emergence. When trees are infested or under attack, managers may monitor the flight of adults with traps. When adults begin flying in problem areas, sprays are applied every two weeks until the flight period is completed. Sprays that may kill adults usually control only a relatively small percentage of the generation, so must be regularly repeated in blocks that are under attack.

## Controls

### Chemical

**Endosulfan** (Thiodan 50WP) is applied at 2.0 lbs. AI/A, usually only once or twice a season, due to label restrictions and a 21-day pre-harvest interval (24c, WA-780033).

**Other products** registered for use to control this pest, but not recommended due to lack of research effort, include **azinphos-methyl** (24c, WA-000007), **chlorpyrifos**, and **phosmet**. Growers use these products, though they are not recommended in the WSU Tree Fruit Crop Protection Guide. Endosulfan sprays are limited to once or twice a season and are inappropriate for late season, so alternatives such as these are sought when trees are under attack by an extended emergence or in late season.

### Cultural

These insects prefer weak or dying trees, so growers are advised to remove those trees or portions of trees that are most likely to be infested. They are also advised to keep trees healthy and vigorous, which is difficult after severe winter weather, and contrary to best fruit quality development. There does not seem to be any significant biological control, as these pests are resident in natural, unsprayed trees outside of the orchard.

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## OTHER INSECTS

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Other insects that cause sporadic damage in some areas of the state include various leafrollers, green and Laconobia fruitworms, cutworms, lesser appleworm, ten-lined June beetle, grape mealybug, fall webworm, oystershell scale, European fruit lecanium scale, Pacific flathead borer, apple ermine moth, and grasshoppers. As we change our pest management practices and control products, we sometimes find that insects that were once suppressed by standard "cover sprays" of the wider-spectrum control materials now cause damage to trees and fruit.

A number of insects of great economic importance in other apple-growing areas are not yet established in the commercial tree-fruit production regions within Washington. High on this list are apple maggot and plum curculio. The introduction of new pests into the region could cause a great adjustment to presently successful Integrated Pest Management control programs.

## Diseases

Apples grown in the relatively dry climate of Washington are generally much less affected by disease than those grown in warm, wet-summer regions. Yet diseases can cause severe losses in certain growing areas and, sporadically, during some seasons. The most important economic losses usually occur as fruit rots in storage, but many of these storage rots may be initiated on the fruit during the growing season. Some of the diseases discussed below damage fruit by marking it, some damage fruit by rotting it, and others damage or kill the tree. Generally speaking, control materials for diseases tend to be fairly specific to a limited number of diseases, and may have little or no effect on others. Control is often marginal, and timing of application to prevent disease is often critical, and of short duration. In many instances, the grower must treat before any signs of the disease are present, as sudden highly damaging epidemics can result from one skipped critical control application.

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### SPECIFIC APPLE REPLANT DISORDER (a complex of pathogens)

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This may also be called specific orchard replant disease. Pathogenic soil organisms present in the soils of most mature orchards often reduce root growth of young fruit trees when the site is replanted. Poor root development leads to reduced vegetative growth and poor fruit yields throughout the life of the replanted orchard. Replant disease is most common when apples or pears are planted after either apples or pears, or when cherries are planted after cherries. Trees may be affected to varying degrees, but they do not die. Control can vary, leading to improved, but not adequate, tree growth. Trees that are growing poorly are very unlikely to produce fruit at positive economic levels. Success of the replanted orchard strongly correlates to the quality of the soil, management of the young orchard, and pre-plant treatment.

While many soil fumigants, fungicides, fertilizers, and soil amendments have been tested for effect on orchard replant disease, only three have so far shown long-term growth and yield benefits in Washington orchard trials: methyl bromide, metam sodium (or metam potassium), and fumigants containing chloropicrin. The other treatments may help early tree growth, but the effect of replant disease can be seen during the second or third leaf, resulting in slightly larger, but sick, trees.

Certain soil fumigants have controlled specific orchard replant disease when properly applied. The positive effect of controlling this disease can be measured the first season and even 20 years after treatment. No soil treatments effectively control replant disease after planting. Demonstration trials and thousands of acres of grower experience since the late 1960s have shown that soil fumigation usually (but not always) leads to excellent tree growth. Some fumigants must be custom applied; others may be applied by a certified private applicator. Some application options described on fumigant product labels have not resulted in replant disease control, so growers are advised to hire a custom applicator or closely follow the label application methods that have proven successful in Washington orchards.

## Controls

### Chemical

**Metam sodium** (Vapam, Soil Prep, Nemasol) or **Metam Potassium** (K-Pam) is used at 31.5 gallons (104 pounds) AI/A for treatment of replant disorder. The entire orchard surface may be treated, or, very often, the products are banded on about 40-50 percent of the soil. The product is carried into the soil by or mixed with sprinkler irrigation water. The rate of water carrier is adjusted to keep the product in the surface two or three feet of soil. Shortly after application, the product breaks down into the more active soil fumigant, methylisothiocyanate (MIT). This substance has low soil mobility, and breaks down into relatively non-toxic substances within a matter of several days. This product is the most practical for treatment of relatively small replant areas or very

rocky soils that can not easily be treated by the shank injectors necessary with the other fumigants. This will soon be the only product that may be applied by the grower. If properly applied, this product is generally as effective as other fumigants for the control of replant disorder.

**Chloropicrin** is usually applied in mixtures with 1,3-dichloropropene as Telone C-17, Triform-35, or Triform-60. These products are shanked into the soil with special, custom-operated equipment, at the rate of 45 to 100 pounds per acre. Rate chosen depends on the history of replant problems in the block, the quality of soil preparation, and soil temperature. The chloropicrin moves only 6-9 inches from the point of injection, so must be applied with equipment that places the product in numerous bands along the treated row. The 1,3-DD portion of the mixture will travel 3-4 feet from the point of injection, which provides control of more mobile organisms, such as nematodes and ten-lined June beetles that could rapidly move from the otherwise untreated drive-row area to re-colonize the treated tree row.

**Methyl bromide** (Brom-o-gas) is usually applied at 400-600 pounds per broadcast acre (applied in bands, which reduces this rate by half) or at one-half to one pound per tree planting site (55-110 pounds per acre) for widely spaced trees. The broadcast applications are done by hired applicators. The grower can do the tree-point applications. This product is highly effective for the control of replant disorder, and is the only one that can be applied easily to single tree sites, without specialized equipment. It is more residual in soil than the other fumigant choices, so is most often used as a fall treatment.

### **Cultural**

If land is left out of orchard production for about five seasons, tree roots are removed, and the land planted to wheat or "green manures," the replant disorder usually is no longer a danger. As family farms have limited acreage, and have no equipment to grow alternative crops in many areas of the state, this is not an economically viable option. Non-chemical control options include the

replacement of soil in the planting hole with good quality soil from a non-orchard source. To be effective, the soil replacement should fill a planting hole 7 feet across and 2 1/2 feet deep. Soil replacement is not practical on a large scale. Using less soil in a smaller planting hole helps the first season or two, but is not a long-term cure. Composts, fungicides, fertilizers, and numerous other products have been tested as planting hole replant treatments, and have not controlled this disorder to the necessary degree.

### **Biological**

There are numerous theories in the popular press about potential biological and cultural control of this disorder. To date, no replanting method has proven as effective as soil fumigation over time in large-scale orchards.

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## **POWDERY MILDEW**

*Podospaera leucotrica* (Ell. & Ev.) Salmon

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Powdery mildew is caused by a fungus that overwinters on the tree in infected buds. As buds begin to grow in the very early spring, the fungus attacks the young foliage and flower tissue, developing spores, which are spread by wind to other host tissue. The mildew can intensify during the blossom period and may attack fruit for two or three weeks after bloom. Foliage may be infected anytime during the season while shoot tips are growing. Fruit infection results in russet of the skin and loss of the potential for fresh market sale. Infection of the foliage can disrupt proper growth of young trees and leads to carryover of the disease to the subsequent season. Most fruit damage occurs during the late pink stage through the ten days past petal-fall stage, and most control efforts are carried out during this period. Later sprays may be applied on younger trees to encourage proper vegetative growth. Many of the more modern, popular varieties are quite susceptible to this disease.

*continued next page*

## Controls

### Chemical

**Sterol inhibitor fungicides** are a group that includes **myclobutanil** (Rally), used at 2 ounces AI/A; **triflumizole** (Procure), used at 4-8 ounces AI/A; **fenarimol** (Rubigan), used at 1.5 ounces AI/A; and **triadimefon** (Bayleton), used at 3-4 ounces AI/A. Triadimefon seems to be somewhat less effective than the others. **Horticultural oil**, 0.5 to 1 percent by volume, in combination with these materials enhances the activity of both products, and leads to most effective control. The growers do not rotate among these products to reduce potential of pathogen resistance, as these fungicides are in the same chemical class.

**Sulfur products** are often used in rotation with other fungicides to help prevent resistance development in the pathogen. Wettable or micronized sulfur must be used when temperatures are over 60°F to be effective, but temperatures above 85°F may lead to fruit and foliage damage. Lime-sulfur or calcium polysulfide may be effective at lower temperatures, but are not recommended when temperatures exceed 75°F. Excessive use of sulfur products may also reduce rust mite populations to levels incapable of supporting the beneficial Western predatory mites, leading to temporarily increased red or two-spotted mite populations. Elemental sulfur products are usually applied at rates equivalent to 6-12 pounds of sulfur/acre. Lime-sulfur is applied at 10 gallons/acre, and calcium polysulfide (Sulforix 27.5) at 2 gallons/acre.

**Kresoxim-methyl** (Sovran 50WG) may be applied at 2 - 3.2 ounces AI/A. Widely used in Washington, with good results. Resistance management is important.

### Alternative

Soaps and/or mineral oils are sometimes applied to control powdery mildew. Results vary, but these give tank-mix options to both organic and conventional growers. There is a significant possibility that either one of these products will mark the skin of fruit if applied when weather conditions are cool and moist, a situation common during bloom when infection is most likely to cause damage.

### Cultural

In small, organic orchards, some growers reduce the overwintering stage by picking off the infected shoots as they become visible in the spring.

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## FIRE BLIGHT

*Erwinia amylovora* (Burrill) Winslow, et al.

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### History

Fire blight is one of the most dangerous diseases in modern apple production in Washington, as all newer apple varieties are quite susceptible, and most are grown on rootstocks that may die if infected. Serious damage was done to about 10-15,000 acres of apples during the 1997 and 1998 seasons, due to abnormally warm weather during the bloom and early post-bloom period. Historically, fire blight has been considered a problem mainly in pears, but apple growers have learned that conditions must be monitored during the bloom period, protective measures must be maintained, and that control requires rapid response.

### Life Cycle

*Erwinia amylovora*, the bacterium that cause fire blight, overwinter only in the blight strikes remaining on host trees. The bacteria may die out in many of these strikes, but from 20 to 50 percent of these cankers reactivate around blossom time and ooze bacteria to their surface. This ooze is attractive to many insects (especially flies), which feed on it, then feed on the nectary (glandlike plant structure that secretes nectar) of nearby apples or pears, transferring the blight bacteria to the flowers' stigma surface. The bacteria multiply on the stigma surface during the first four days the flower is open. If the weather is warm, the bacteria grow rapidly, form the necessary large colony, and then are washed gently into the flower's nectary by water (usually from rain or heavy dew). If the colony is successful in attacking the small fruitlet, the bacteria spread into the phloem of the tree, killing any young, tender parts of the nearby structures.

It takes five to fourteen days after infection for symptoms to become easily seen by the casual observer. During the blight attack, the bacteria stream inside the tree well ahead of the visible symptoms. They often move into other more sensitive portions of the tree, such as the nearby shoot tips or the susceptible rootstock, causing more blight strikes and bacterial build-up. In apple trees younger than seven to ten years, the bacteria often kill the tree by attacking the highly susceptible rootstock, even if the blight has been removed from the tree within two weeks after infection. If the tree does not die, the bacteria form a mass along the living edge of the current season strike, and overwinter in a dormant state.

Fire blight in the Pacific Northwest was once rare. The weather during bloom is generally too cool (68°F or less daily) for primary blossom infections. Most infections take place on blossoms that appear after petal-fall. These “side blooms” or “secondary blooms” appear on the apple tree shortly after bloom as the weather begins to warm, usually during May, while weather is warm but not hot. These late blossoms are much more common on modern varieties growing on modern rootstocks.

## Controls

### *Cultural*

Clearing the orchard area of active blight strikes that act as a source of bacteria is the key to suppression of this disease. The amount of infection can be reduced to manageable levels if effective sanitation and well-timed effective sprays are used in conjunction. Sanitation reduces, but does not eliminate, danger of infection. On the other hand, without sanitation, no spray is adequately effective during high-risk infection periods.

Antibiotic sprays must be applied within the period twenty-four hours prior to infection through twelve to twenty-four hours after infection. Biocontrol sprays must be applied about three days before the potential infection. In order to properly time the sprays, growers and advisors must closely monitor weather and weather forecasts and use infection models to determine potential time of infection. Poorly or randomly timed

sprays are not often effective. Best control is attained when growers carefully sanitize the orchard during the winter, apply biocontrol products to blossoms during a warming trend when models indicate infection risk will rise into dangerous levels over the next three days, and spray with oxytetracycline within 24 hours prior to infection, or as soon as possible after models indicate infection has occurred.

### *Chemical*

**Oxytetracycline** (Mycoshield) is recommended at 1 pound of 35.2% product per 100 gallons of water, sprayed in a volume per acre sufficient to completely wet the interior of the flowers. This product is the only reasonably effective spray material available to most Pacific Northwest pear and apple growers. There have been many instances over the past two seasons where the properly timed use of this product has greatly diminished the degree of infection in the treated block, compared to untreated nearby blocks. This product has been fully labeled for use on Washington pears for decades, but is available only from year to year on a Section 18 (01-WA-05) specific exemption.

A wide range of **copper**-containing products are registered for the control of fire blight on apples. Copper, applied during the poor drying conditions common during the blossom period, often marks the fruit, causing serious economic loss. Copper will provide some measure of control if applied frequently, but growers would have to risk the value of their crop every season to reduce the risk of fire blight, which occurs only sporadically. Copper, though available as a control product for over 100 years, has never been an effective, practical blight control.

**Streptomycin** is fully labeled on apples, but has not been effective since the 1970s, when the *Erwinia amylovora* in the region developed resistance to it. Use of this product likely increases the potential for fire blight in the block, as it may decrease the level of natural biocontrol that may exist in the flowers. There is no area in Washington where this product is effective.

**Fosetyl-aluminium** (Aliette) is registered for control of fire blight, but both research and grower experience indicate it has very little inhibition on either the infection process or the progression of the disease in treated trees.

### **Biological**

*Pseudomonas fluorescens* (BlightBan, the A-506 strain of *P. fluorescens*) are live bacteria that produce colonies on the stigma surfaces, sometimes protecting blossoms and spreading to protect newly opened flowers. The beneficial bacteria must colonize the stigma surface two or three days ahead of the blight bacteria in order to protect the stigma. Colonized stigma surfaces are well protected, but the practical difficulty has been attaining a continuous high level of infestation of flowers by the protective bacteria. If flower numbers are low, as they are late in bloom or post petal-fall, or when the weather is cool, the bacteria do not grow and spread adequately. The biological products will be most effective when applied to a heavily flowering orchard at the beginning of a warming trend, rather than during cool weather during a specific blossoming stage. To date, research has shown that biological control agents provide partial reduction of blight infection, as high as 50 percent in field tests, and even higher in the laboratory. If applied two or three days ahead of an actual infection, this 50 percent control will be in place when the more effective control product, oxytetracycline, is applied. The two products used in this timing pattern, not together, are the best control presently available.

### **Other Issues**

Fire blight has not yet been found in many important potential overseas trading partners, and has been historically used as a “non-tariff” trading barrier. In order to send fruit to countries such as Japan, growers must demonstrate complete fire blight control during the growing season.

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## **APPLE SCAB**

### *Venturia inaequalis* (Cooke) Wint.

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### **History**

Worldwide, apple scab is the most common serious disease of apple. It is one of the most studied and best understood diseases on earth. However, unless there is a radical change in the varieties of apple that the public prefers to consume, growers will continue to produce susceptible apples in regions where apple scab thrives.

Apple scab (AS) is much less of a problem in most Washington orchards than it is in regions with appreciable rainfall during spring and summer. It is a problem every season in the wetter portions of the state. Areas that have AS pressure yearly include those in the far Northwest and near Spokane. In the remainder of the production region, AS causes significant losses only when two wetter-than-usual springs occur in succession. The disease increases from less-than-noticeable levels to a trace of damage the first wet spring, then greatly increases during the second wet spring unless controlled. Advisors watch the packinghouse cull report for signs of building apple scab following a spring with potential scab infection.

### **Life Cycle**

Apple scab is caused by a fungus that lives best on leaves, but will attack fruit skin in the early spring or the three or four weeks before harvest. It overwinters on the ground, on fallen infected leaves. In the late winter and throughout spring, the fungus develops fruiting structures that expel spores each time they are wetted. These spores drift in the wind and attach randomly to anything they contact. If the spore attaches to the surface of an apple leaf, or young fruit, and remains wet for the required length of time, it germinates, penetrates the tissue surface, and becomes established within the tissue. The number of hours that the spore must remain wet on the leaf surface in order to become established has been carefully modeled. Most growers and advisors are well aware of the Mills Table, which outlines the relationship be-

tween wetting, temperatures and apple scab infection. In many instances, determining if infection may have occurred is complicated by the lack of data specific to each orchard in the region that may have been affected by marginal infection conditions.

The infected spots that become established on a tree produce many thousands of spores, which may greatly increase the potential for further damage in the orchard. Growers are advised to put their primary control efforts into preventing the establishment of scab on the tree, as the secondary spread from early infections is very difficult to control. After some time in June, the spores no longer are produced from the overwintering stage on the ground surface. The fruit and leaves become less susceptible to infection, and growers who have no scab infection in the orchard stop prevention programs.

Orchardists who have a problem with apple scab must protect their fruit during the month prior to harvest. The infection of fruit is uncommon, as the fruit surface must remain wet for twenty-four to forty-eight hours before the fungus becomes established, and long wet periods are rare in the dry areas of the state. However, the fall-infected apple scab damage is not visible at harvest, and appears as “pin-point” or “storage scab” on the fruit after it has been stored. This in-storage damage is very expensive, and growers take great care to prevent it.

## Controls

### Chemical

Growers have two general ways to approach the chemical control of apple scab: (1) apply fungicides prior to infection to protect the tree and fruit, or (2) apply fungicides after infection in an effort to stop the progress of the infection process. The protective method is usually the most effective, as spring wet periods may last for extended periods, and the weather between wet periods may be windy and cool. Growers with a history of apple scab may choose to protect their orchards with fungicides during the most critical pink through ten-days-past-petal-fall infection period, then turn

to post-infection sprays during the remainder of the potential infection period. Orchards with lower apple scab pressure are usually treated after an actual infection period has occurred. This may greatly reduce the amount of spraying, if weather is generally dry.

Mixing a combination of protective and post-infection fungicides provides the best control during severe infections. These mixtures are often applied with lower rates of both products than would be usual if the products were used singly.

**Protective fungicides.** The following fungicides have modest or no post-infection activity. They must be applied prior to infection, then may be moved around on the tree by rainfall, protecting unsprayed portions of the tree. Some of these protective fungicides also protect the fruit from fungi that cause post-harvest losses, but infect the fruit in the orchard. Those most useful for this cross-protection include captan, mancozeb, ziram and thiram. Resistance management is a large concern. Growers may use 5-6 sprays/growing season, and thus need a considerable variety of fungicides in order to both obtain good results and practice resistance management. The products listed below are not listed in order of importance, and for the reasons just mentioned, should all be retained.

**Captan** (Captan 50WP) is applied at 2-3 lbs. AI/A, most commonly during the 2-3 weeks after bloom in combination with a sterol-inhibitor fungicide. It would be used more if foreign markets did not prohibit its use in the orchard. This product goes well with the sterol-inhibiting fungicides.

**Dodine** (Syllit 65WP), applied at 1.3 to 1.95 lbs. AI/A, has both protective and post-infection activity. At one time, this was the best available product, but resistance has developed in some regions.

**Lime-sulfur** used at 8-10 gallons of product per acre is the most active product available to organic orchards. It is sometimes used by conventional growers very early in the season because it reduces mildew and rust mites.

**Mancozeb** (Dithane M-45) is used pre-bloom at 2.7 lbs. AI/A. This could be a very effec-

tive protective fungicide, but the current allowable rates are too light for effective use. This product is most useful in the early season, therefore if label amendments were made to increase the rate and limit the use to early season, it would be more widely used. Mancozeb goes well with sterol-inhibiting fungicides.

**Metiram** (Polyram) is not often used, as the 3-pound-per-acre per-application rate does not appear to be sufficient to provide control in difficult scab control situations.

**Thiram** (Granuflo 75WDG) is effective at its recommended rate range of 3.9 to 5.1 lbs. AI/A.

**Ziram** (Ziram 76WDG) is used at 3.8 lbs. AI/A, mostly around the bloom period or, more commonly, as a pre-harvest protectant in orchards with a current-season apple scab problem.

**Post-infection fungicides.** Fungicides in this group may be applied for twenty-four to ninety-six hours after infection. Degree of control is usually improved by applying the product as soon as possible after infection. In most instances, the fungicide must contact the leaf or fruit on or very near the site of infection. Those portions of the tree contacted by these products are well protected from further infection for several days, but portions of the tree that grow after treatment are open to infection. Most of these products also control powdery mildew, so applications cross-protect the tree from these key foliage-infecting fungi. As the fruit grows to a size greater than a pea, many of this class of fungicide continue to control the disease on leaves, but lose effect in preventing fruit damage. Growers are advised to tank-mix these products with a protectant fungicide to reduce this problem. All sterol-inhibiting fungicides need to be managed for resistance development as a class, and are rotated with fungicides with different modes of action.

**Fenarimol** (Rubigan 1EC) may be applied at 12 ounces of product per acre (0.094 lbs. AI/A), and continues to be commonly used, especially in combination with a protectant fungicide. This is a sterol-inhibiting fungicide.

**Myclobutanil** (Rally 40WP), applied at 2 ounces AI/A, is a sterol-inhibiting fungicide very

commonly used as a mildew control. Is often part of the apple scab control program.

**Triflumizole** (Procure 50WS) is recommended at 4-8 ounces AI/A and is very commonly used as a mildew control, so is often part of the apple scab control program. This is a sterol-inhibiting fungicide.

**Triadimefon** (Bayleton) is recommended at 3-4 ounces AI/A. This was one of the first sterol-inhibiting fungicides sold to apple growers, and is considered more effective at mildew control than apple scab control. Growers rarely include it in their apple scab management program.

**Kresoxim-methyl** (Sovran 50WG) is effective at its recommended rate of 0.5 to 0.8 ounces AI/A per use, no more than 0.8 pounds of product per acre per season.

### **Alternative**

Apple-scab-resistant cultivars are available. None of these has reached commercial status. They are primarily being grown in high-pressure apple scab areas of eastern states, or in the wetter areas of the West. Quality of the fruit is not up to the general public's standards. An effort is underway to induce apple scab resistance in currently popular apple varieties through genetic modification, but the public seems highly skeptical of this approach and political pressure is building against it.

### **Cultural**

As the overwintering stage of this fungus lives on infected leaves that drop to the ground, growers are often advised to manage the leaves. When orchard infection is moderate or severe, growers are advised to spray the leaves with nitrogen fertilizer, then rake and mow the leaves. Research has demonstrated that this treatment may speed the decomposition of the infected leaves, reducing the number and duration of apple scab spores in the subsequent spring infection period. This is part of the management program in only a few orchards, as a reduction in spore numbers and a shorter spore production period has not reduced the amount of damage in orchards. In other words, this does not work.

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## **COLLAR ROT** *Phytophthora* spp.

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A fungus, *Phytophthora*, causes this disease. It lives in almost all soils. It attacks the roots and the trunk in the area immediately below the soil surface. The fungus kills the cambium (soft, formative layer) of the roots and collar, cutting the roots' access to the upper portion of the tree, causing gradual starvation and subsequent death of the tree. Symptoms include rust-colored darkening of the cambium just below the soil line, and an early purple coloration of the tree in the fall. Some rootstocks (e.g., M106) are much more susceptible than others (e.g., M9), but all may be attacked if the trees are in poorly drained soils or if cold winters damage the roots and collar. Treatment is usually started after symptoms are noticed in the orchard, which is often too late to save the more affected trees. The two products that seem to work best are fosetyl-aluminium (Aliette) and metalaxyl (Ridomil). Metalaxyl must be applied as a drench around the root collar, which is almost impossible in an orchard, so the product is probably not effective in the field. Fosetyl-aluminum may be applied to the foliage via sprayers, so is more effective.

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## **BULL'S-EYE ROT/PERENNIAL CANKER** *Pezicula malicorticis* (H. Jacks)

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Bull's-eye rot is the most important post-harvest apple disease in Washington caused by a pathogen that also attacks the tree. The disease is called bull's-eye rot on the fruit and perennial canker on the tree.

The fungus, *Pezicula malicorticis*, enters the wood on the tree through wounds, often caused by pruning or winter damage. The fungus survives the winter along the edge of the area it attacked, producing spores that re-infect the tree almost any time of season when weather is cool and wet. Peak infection danger is usually between October and February. Each year, the canker reactivates, kills a

narrow zone around the old canker, and then slows its activity. Over the years, the disease moves slowly outward from the center, leaving concentric rings of dead bark, giving the canker a distinctive appearance and thus the name to the disease.

Fruit becomes infected when contacted by spores anytime between petal-fall and harvest. As the spores are dispersed by rain, infection is most common in the spring and late fall. Rot occurs in storage, even at very cold temperatures, and may cause serious economic losses, especially in fruit from older blocks, and in wetter than normal seasons. Post-harvest fungicide treatments are more effective in reducing rot from late season fruit infection.

### **Controls**

#### **Cultural**

Most of the important post-harvest fruit rot fungi are generalist feeders, living on decomposing plant matter and attacking almost any wounded fruit. Poor sanitation in the orchard or packing-house compounds disease problems. Most effective control results from careful sanitation of the orchard, which entails removal of the cankers, and control of woolly aphid, which plays a role in yearly re-activation of the cankers when it feeds around their edges. Sanitation is difficult in large, older trees that have been damaged by a number of severe winters.

#### **Chemical**

Protective fungicides are applied in the wetter periods of spring and fall in orchards known to have the problem. Many of the products listed under apple scab protective fungicides are effective when used for bull's-eye rot prevention. **Ziram** is most commonly used; **Captan** and **Thiram** are also used.

*continued next page*

## Weeds

During the 1950s, in a successful effort to halt soil erosion from cultivated hillside fruit orchards, almost all apple orchards were converted to a grass cover crop with a six- to eight-foot wide uncultivated weed control strip under the trees. Weeds are controlled to facilitate sprinkler water distribution, reduce the numbers of tree-damaging voles, reduce the build-up of damaging insect and mite species, conserve water and nutrients, reduce health hazards to orchard workers (poison oak and rattlesnakes), and improve the overall health of the trees. Weed control is difficult in organic orchards, where it is generally neglected (to the detriment of the orchard) or is carried out by mechanical means. Mechanical weed control is difficult, unless the orchard was grown from an early age with this method in place. Mechanical weed control greatly disturbs the soil, increasing soil loss during irrigation or high intensity precipitation.

Growers provide financial support to county weed boards, which help prevent the introduction of serious weed species into the region, and control those that have been recently introduced.

Weed species include dandelions, many other annual and perennial broadleaf and grassy weeds, and some noxious weeds such as Canada thistle. Blooming weeds are the most problematic for growers, both in terms of competition for pollinating insects, and insecticide use/pollinator protection issues. No single weed species drives herbicide application in Washington orchards. For that reason, weed control is discussed in general terms using both residual and contact herbicides.

## Controls

### *Chemical*

Herbicides are applied at a per-surface-treated-acre rate, but are banded only under the tree row, so actual rates applied per orchard acre are about 35-40% of the amount allowed per acre on the label. Herbicides are generally applied at lower than allowed per acre rates to provide for tree safety. Individual products do not control all possible weeds, so are almost always applied in

combination. The most common herbicide combinations are two residual products plus a contact systemic herbicide to control emerged annual and, especially, perennial weeds.

### *Residual Controls*

**Simazine** (Princep) is usually applied at 1.8 to 2.7 lbs. AI/A (about 0.7 to 1 lb. per actual orchard acre.) The product is often applied in the fall, after harvest, or in the spring. It is considered the safest effective residual herbicide for use on all but the sandiest, shallow soils. It is usually mixed with norflurazon or oryzalin to enhance the spectrum of weeds controlled. A contact herbicide, usually glyphosate, is almost always applied in the mixture. The most common herbicide mix used on apples in Washington is 2.7 lbs. Simazine, 1.0 lbs. norflurazon and 3 quarts of glyphosate. Residual control of weeds usually lasts most of the growing season when this mixture is applied.

**Norflurazon** (Solicam) is usually applied at 1.0 to 1.5 lbs. AI/A (0.4 to 0.6 lbs. AI/orchard acre) for summer annual grasses, which are difficult to control with other available products. The product is quite residual, so growers reduce their application rate to 1.0 lbs. AI/sprayed acre after the first year of use.

**Oryzalin** (Surflan) is applied at 2.0 to 4.0 lbs. AI/A (0.8 to 1.6 lbs./orchard acre). Oryzalin is the most effective and tree-safe product for use on newly planted or young orchards. It is often used where soils are sandy, rocky, and shallow, where a number of other residual herbicides could cause tree injury.

**Diuron** (Karmex) is most often applied on finer textured soils at 1.6 to 3.2 lbs. AI/A (0.6 to 1.3 lbs. AI/orchard acre). It is a substitute for Simazine in the herbicide mixtures, as it has a similar weed control spectrum, but is used less than Simazine because it is more hazardous to the tree. Is often rotated with Simazine for resistance management.

**Terbacil** (Sinbar), at 0.8 to 1.6 lbs. AI/A (0.32 to 0.64 lbs. AI/orchard acre), is usually applied as a mixture with Diuron and a contact herbicide. It is considered safe to use only on more mature orchards on finer textured, deep soils.

Other residuals less commonly used include **pronamide** (Kerb), **napropamide** (Devrinol), **oxyfluorfen** (Goal), **pendimethalin** (Prowl), and **isoxaben** (Gallery). These products are used less than the others due to one or more of the following reasons: poor performance, difficulty of application, high expense, and/or limitation to non-bearing orchards. All have useful applications in special orchard situations.

### ***Contact, Non-Residual Controls***

**Glyphosate** (Roundup) application rates vary from 0.75 to 3.0 lbs. AI/A (0.3 to 1.2 lbs. AI/orchard acre). Proper use of this product has eliminated most perennial weeds as a problem in most orchards. It has been especially useful in control of perennial grasses and field bindweed, which has allowed growers to reduce the rates of residual herbicides. Some growers apply this product at very low rates in mid-summer to clean up weeds that have escaped earlier control efforts so that weeds remain small during the critical mid-summer through harvest period. This product cannot be safely applied to the trunks of younger, smaller orchard trees.

**Paraquat** (Gramoxone) is applied at 0.31 to 0.94 lbs. AI/A (0.125 to 0.38 lbs. AI/orchard acre). This product is commonly used as a “chemical hoe” in younger orchards because lower rates can be applied to the tree trunks safely. As it controls only small, emerged annual weeds, it must be applied as newly emerged weeds approach 4-6 inches in height. Unless it is tank-mixed with a residual herbicide, it must be applied as many as three to four times per growing season to maintain weed control in the young orchard. As it will not adequately control perennial weeds, it is rarely used in mature orchards.

**2,4-D** (amine formulations) are generally applied at about 1.4 lbs. acid equivalent/acre (0.56 lbs. acid equivalent/orchard acre). As this product will not kill target weeds when applied at this rate at the proper timing, its use is declining. It is most used at the lower rate range in combination with other products, such as glyphosate, to enhance control.

### ***Cultural***

Mechanical weed control is used as an alternative to chemical **only** in organic orchards or those converting to organic. This constitutes about 3,800 of the more than 200,000 apple acres in the state. Mechanical control disturbs soil, increases the threat of soil erosion, and increases the rate of organic matter breakdown. Orchard sprinkler systems must be designed to allow mechanical weed control, therefore most growers find it difficult to start this method in a conventional orchard. Other alternatives have been researched including plastic mulches, which have not worked well past the second season of use, are very expensive, and pose a waste disposal problem when they no longer work. Organic-based mulches have been applied in orchards with tree-growth problems and weed control is an added benefit. Mulching materials are limited in supply, very expensive, and may contribute to rodent build-up. Some growers are experimenting with flaming, steam, or hot water sprays, which have not worked well yet, often damaging trees, polluting the air, and consuming fossil fuels.

### ***Biological***

Biological weed control plays almost no role in orchards.

### ***Rodents***

Short-tailed meadow mice can cause significant damage to an orchard. During snowy winters, they sometimes chew the bark off of the lower portions of trunks, especially on younger trees. While growers try to save these damaged trees with approach grafts or bridge grafts, these methods are very slow and expensive, and do not always work well. There are no mouse poisons on the market that will economically control large populations of mice in the fall (as Endrin once did). Mouse control is a season-long effort; reduction of mouse cover is the key component. As mice do not travel far, the key mouse cover is the grass and weed cover crop. Well-mowed grass and a fairly clean weed strip is the most effective mouse management program. Pocket gophers and meadow voles

can work their way in from surrounding areas and create disturbance as well.

## Controls

### Chemical

**Zinc phosphide** treated baits are most commonly used for short-term, spot reduction of meadow voles in higher population areas of the orchard. A few ounces are applied per treatment site, scattered in the area showing mouse activity. These baits are applied in the fall, prior to wet weather. If the soil surface is wet, the active ingredient is rapidly diminished. If the bait is spread thinly, non-target animals are rarely exposed. If the mice are under-exposed at first feeding, they become bait-shy, and are difficult to control.

A number of **anticoagulant** products are registered, mostly as baits, but one as a spray. Rozol liquid (24c, WA-780060) and Rozol Bait (24c, WA-780061) are the two products most commonly used. The bait is applied at 10 to 20 lbs. per acre to relatively dry soil in areas with little grass or weed cover. The liquid is sprayed in 100 gallons per treated acre at 1-2 pints per treated acre, in low weed and grass growth. Very often, only the areas showing the most signs of mouse activity are sprayed. The mice must feed on these products repeatedly to obtain a critical dose. These products are more active in wetter weather, but are generally considered less effective than the faster-acting zinc phosphide. The sprayed product is used in areas with high populations and poor prospects of adequate bait exposure. These baits are generally considered safe to non-target animals, but may cause occasional problems when pet dogs or cats trespassing in orchards consume an overdose of dead mice. This condition is treatable by veterinarians, and is seldom fatal.

**Strychnine**, sold as strychnine-treated oat bait, is available as pocket-gopher bait. It is placed by hand-held applicator inside the underground runways. This prevents the exposure of non-target animals to either the bait or the gopher carcass.

### Cultural

Weed control and frequent cover crop mowing are relatively effective in keeping mouse popu-

lations at manageable levels within the orchard. There can be fall migration of mice from the non-orchard land near the orchard, but usually no farther than the outside first row or two. Added control efforts can often be concentrated in this part of the block. Gophers often work their way into orchards from the surrounding habitat. Trapping in newly infested areas of the orchard is a relatively effective, but labor intensive, way to reduce low populations of this pest. Once gophers become established in the block, trapping is supplemental to chemical control.

### Biological

Cats, dogs, snakes, predatory birds, and coyotes all help reduce the population of rodents. Without biological controls, there would soon be many thousands of mice per acre of orchard. Cover management allows the biological control to take place. Traps and chemical controls are necessary to lower the rodent population in those areas where biological controls have fallen short.

## Registration Needs

Because of the difficulty in monitoring and managing mullein plant bug as outlined, growers need a control product that can be applied during bloom that is effective, yet safe for honeybees.

Growers also need the **mancozeb** (Dithane M-45) label amended to allow an increased rate of application as described under the apple scab section (pp. 25-27).



**Gala apples.**

Photo: Tim Smith, WSU Extension.

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## College of Agriculture and Home Economics

**Use pesticides with care.** Apply them only to plants, animals, or sites listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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