Crop Profile for Apples in Michigan

Prepared: August, 2004

General Production Information

- The 2001 Michigan apple crop was 880 million pounds with a farm gate value of $81.6 million, up from 800 million pounds in 2000 (valued at $74 million) (17).
    - Michigan ranked third in U.S. apple production in 2001 behind Washington (5.1 billion pounds) and New York (1.0 billion pounds) (17).
    - Michigan produces an average of 7-11% of the nation’s apple crop (6).
    - Michigan is the nation’s leading supplier of apple slices for makers of frozen apple pies and pie filling (8).
- Apples are Michigan's largest crop on an acreage basis (6).
    - There are approximately 47,500 acres of apples containing around 8.56 million trees (9).
    - The density for plantings from 1992 through 1994 was nearly 300 trees per acre. There were one thousand acres with at least 500 trees per acre. (9)

- There were 1,100 commercial apple farms in 2001 (9).
- Kent leads all other Michigan counties with 10,300 acres used for apple production (17).
- The top five apple varieties in total acres were Red Delicious, Golden Delicious, Jonathan, Rome and Macintosh (9).

- Michigan's 1997-2001 production average was 968 million pounds (8).
  - Per acre yield in 2001 was 20,000 pounds (17).
  - The average utilization of Michigan apples is about 270,000,000 pounds for fresh market and about 580,000,000 pounds for processing (17).
  - Approximately 5% of Michigan apples are processed by the baby food industry. Michigan is home for Gerber Products, the baby food industry leader accounting for 65 % of the market (11).
  - Apples make up 62% of the total pounds of fruit produced in Michigan (8).

PRODUCTION REGIONS

In 2000, ninety per cent of Michigan's 1,100 apple farms had 99 or fewer acres. Seventy-three farms had between 99 and 200 acres and 47 farms had more than 200 acres. The largest Michigan apple production areas are near Lake Michigan, from the Indiana border to as far north as Charlevoix. The top five apple producing counties are Kent (10,300 acres), Berrien (5,300 acres), Van Buren (5,200 acres), Ottawa (4,000 acres) and Oceana (3,550 acres) (17). There are also many orchards in the inland portions of the southern half of the Lower Peninsula, including the fringes of the Detroit metropolitan area (8).

CULTURAL PRACTICE

Apple trees in traditional free standing orchard systems (150 - 250 trees/A) take four to five years to mature and about 10 years before the trees reach their maximum yield. The 2000 orchard survey shows an 11% increase in high-density plantings across Michigan since 1997 and a sharp rise of such plantings in middle-sized operations. High-density plantings use trees on dwarfing or size-controlling rootstocks and contain 500 - 1000 trees/A. Benefits of high-density orchards include earlier bearing; higher production per acre, quicker return on investment; training, pruning and harvesting from the ground;

potential increased fruit quality and greater pesticide application efficiency. High-density orchards, however, require a high initial investment to cover the cost of trees, a trellising system to support the trees and an irrigation system. Training and pruning techniques for high-density orchards are different from traditional orchards with most of the work occurring in the summer rather then the winter. Cultivars selected for the high-density orchard must produce fruit of adequate market value to quickly recover the cost of establishment (24).

Apples are grown mainly on hilly terrain in Michigan. This is necessary to prevent the annual spring frosts from destroying a good share of the crop. The soils are generally sandy loam to loam soils with good drainage. About half of traditional orchards and the majority of high-density orchards receive supplemental irrigation.

Pruning and training are important cultural practices in growing apples. The shape of the tree needs to be modified yearly to ensure that sunlight can get through to the inner branches. Training is an important summer activity.

Fruit thinning is an annual practice. Pre-harvest growth regulator applications to enhance fruit color and harvesting are also used in some blocks. The major fruit thinners used in Michigan are Accel, Sevin and NAA; NAD and other various bloom thinners are also used to a lesser extent. If thinning agents were lost, there would be enormous ramifications to Michigan apple growers. If growers had to thin entirely by hand, labor costs would increase, apples would be smaller and trees would only bear fruit every other year (20). However, hand thinning occurs annually on some portion of the apple acreage due to poor performance of chemical thinners.

Apples have the longest harvest season of any Michigan fruit, starting about mid-August for the late-summer varieties and extending into late October and early November for the latest fall varieties. Apples kept in controlled-atmosphere storage with low oxygen and cold temperatures can be held six months or more and retain just-harvested quality (8).

Worker Activities

Hand labor activities in Michigan apples include:

Pruning
Nearly all of Michigan’s commercial apple acres are pruned by hand using pneumatic equipment such as pruning towers and long handles loppers. There are a limited number of growers who use mechanical pruning techniques, which generally need some follow-up hand pruning. Some of the young, non-bearing orchards are pruned from the ground with hand pruners and/or loppers.

High-density plantings require training and pruning primarily during the summer to control tree size and encourage fruiting early in the life of the tree with minimal dormant pruning. The exact methods and timing used depends on the type of support system used.

In traditional free-standing orchards, tree pruning begins as soon as some varieties are harvested in the fall, but about ¾ of the pruning effort typically takes place after the first of December. Depending on the variety of apple, some trees are pruned in the summer months to improve light penetration to the fruit for increased fruit color. About 25% of Michigan's apple acres are summer pruned. However, the increased use of plant growth regulators is reducing the need for summer pruning. Depending on the overall size of the tree, it can take anywhere from less than a minute to nearly 30 minutes to prune an apple tree. Most growers are moving to dwarf-type trees that usually take less than 5 or 10 minutes per tree to prune. Most workers trim 8 to 10 hours per day.

There is sometimes a need to prune out infected plant tissue (strikes) due to infection by bacterial fire blight. Infection usually occurs in May and June and removal of strikes is done typically in June and perhaps into July depending on when the infection occurred. This activity would require an average workday of time, but the total time needed would depend on the severity of the infection and the quantity of susceptible varieties in the orchard.

Rodent Protection
White plastic tree guards are typically used on every tree to protect from the gnawing of mice and rabbits in the winter months. These are usually applied soon after planting. Newly established orchards receive little to no pesticide applications the first year of planting.

Mulching
Some growers, organic-based in particular, use mulches to help with weed control and soil moisture retention. Mulches are often applied in the spring to the base of the trees along the length of the rows. Depending on the thickness of the mulch and available labor, the mulch is pulled back away from the tree trunks in the fall to prevent rodent damage. Both the laying down and the pulling away of mulches would require workers to be in orchards for an average workday. The amount of days for these activities depends on the acres covered with mulch.

Hand Thinning
Nearly all of Michigan's apple orchards require some thinning of fruit to ensure a marketable product at harvest time. Much of this thinning is done chemically, but there is a need to do some of the thinning work by hand. Hand thinning is primarily done from the middle of June until the first of August in Michigan, but some growers will hand thin all the way up to harvest if it is deemed necessary to ensure fruit size and quality. A worker will typically work 8 to 10 hours doing hand-thinning work per day with the majority of work being done in the early summer. It would be typical for a worker to do 10 to 14 days of hand thinning work per season.

Limb Manipulation
Apple tree limbs are manipulated in some of the higher density apple plantings to increase fruitfulness and reduce overall vegetative growth. This is typically done in non-bearing trees to establish a tree framework for fruit production. Non-bearing trees receive limited pesticide applications because there is little fruit that needs to be protected for the first 3 or 4 years after planting. Limbs are manipulated via tying to wire trellis systems or posts inserted next to the trees or through the use of spreaders (wooden or plastic pieces inserted between the limb and the trunk of the tree). This activity is usually done when branches are supple (May - August). Workers tie or spread branches with 2 to 5 ties/spreaders per tree and work an average day. Branch manipulation is typically done after the spring apple scab season sprays are completed and between necessary internal feeder sprays.

Suckering
About half the apple orchards in Michigan have workers in the orchard from late June through July to remove suckers (watersprouts) arising from the larger limbs of the tree. This activity involves close contact with the foliage and a worker will typically work a full day at a time (8 to 10 hours per day).

For the root suckers that sometimes arise from the base of the tree trunk, some growers use a contact herbicide in the row and do this task chemically. Not all apple rootstocks produce root suckers so this activity is only done in about 30% of the orchards. A few orchardists may send a work crew through with loppers to cut off root suckers, but this is an expensive alternative and typically avoided.

IPM Scouting
Scouting is done in about 70% of the apple orchards. A scout, hired by the grower, or chemical distributor, will assess the orchard on a weekly basis for signs of pests and disease. Most scouting is done with a walkthrough of the orchard in a random pattern from week to week with the scout assessing the foliage near insect traps or where he/she sees symptoms. The typical scouting season starts around May 1 and continues until September 1. Scouts may spend 4 to 5 hours per day in orchards with the remainder of the workday in travel or meeting with growers to discuss their reports.

Also included in scouting activities would be the collection of soil and tissue samples. This would require only a short time (1 to 2 hours) in an orchard block per season and is usually done every 3 to 5 years per block.

Repairing Irrigation
Irrigation in apple orchards is common in about 50% of the orchard blocks in Michigan. It can be done by several methods, but is most commonly a permanent trickle irrigation system. There are some orchards that rely on overhead irrigation through the use of large aluminum piping that needs to be set up in the orchard when it is needed. In all irrigation systems, the need for repair can occur at any time during the growing season and requires immediate attention. There is also the need to blow out lines for the winter months to prevent damage to the lines. This is typically done in the fall after harvest.

Fixing Trellis

Many high-density orchard systems rely on wire trellis systems to hold the trees up. There is a need each year to repair trellis systems. This activity is usually done in the summer months when time allows and does not require a great deal of field time for routine repairs.

Setting up trees, re-tie trees, replanting
Storms with high winds can knock trees over, requiring the re-setting of trees and re-tying to their stakes or wire trellis or both. This activity would be necessary only in the event of a major storm that results in tree damage. Replanting of trees is typically done in the very early spring, usually before growth begins and before any pesticides are applied.

Mechanized labor activities in apple orchards include:

Spraying
The grower or a family member does most of the spraying. An average 7-day interval between sprays is typical for apple pest management programs with the majority (75%) of pesticide application being made in late April through mid June for apple scab prevention. Sprays to trees are mostly applied with ground equipment (air blast or tower sprayers). Herbicide applications are made with low volume sprayers. Typically there is an enclosed cab tractor dedicated to pesticide applications.

Mowing
Orchard floors are routinely mowed 2 or 3 times per season to reduce pest levels (weeds and insects) and to make the orchard conditions more favorable for workers to walk through for required activities. Mowing is done with a tractor and attached mowing implement and requires very little contact with the orchard at all. Enclosed or non-enclosed cab tractors are typically used.

Bin Placement
Apples are harvested into 20-bushel bins that need to be placed in the orchard prior to harvest. This is typically done about 2 to 3 weeks before harvest. It is mostly mechanized with the use of a tractor with lifting forks. Bins are brought to the orchard on a truck or trailer or by the use of box haulers. Box haulers can move the bins into place one at a time with little contact by the worker in the orchard. If bins are moved to the block in nested bundles, they need to be unbundled and then moved down the rows. Again, there is little contact with tree foliage or ground in this activity, as most of the work is done from a tractor.

Harvest
Harvest timing: Mid-August through the first of November, with the majority of harvest taking place from mid-September to late October.

All apples are harvested by hand. Workers use picking buckets to move fruit from the trees to the 20-bushel bins used to store fruit. Fruit is reached from ladders where needed, but dwarf planting allows for

much of the fruit to be harvested from the ground. Workers typically put in a 10 to 12 hour day during the busiest of harvest times with most picking 7 to 10 bins per day.

Insect Pests

Codling Moth
Cydia pomonella (Linnaeus)


Codling moth (CM) is the most important major pest of apples in Michigan and causes in excess of 80% injury to the fruit if left uncontrolled. The larvae tunnel into apples making the fruit unmarketable – entire truckloads of fruit may be rejected if wormy fruit are found. CM has traditionally been controlled with organophosphate insecticides. However, insecticide resistance is becoming a problem (4,15).

Life Cycle: There are typically two generations of codling moths per year in Michigan, with a partial third generation in exceedingly warm years (14). The insects overwinter as mature larvae in cocoons under loose bark of trunks and limbs and in leaf litter under the trees. Adults emerge in the spring about the time of Red Delicious bloom. They are grayish brown, criss-crossed with fine alternating gray and white bands. Near the tip of the forewings are bronzed scales characteristic of the codling moth. The adults lay eggs on the fruit or nearby leaves. The eggs hatch in 6 to 14 days and the tiny (2 mm) white larvae with black head capsules burrow into the apple. After feeding within the apple for three weeks and creating large tunnels, the larvae, now pinkish-white with a brown head capsule and about 13-15 mm long, emerge to find a pupation site. After two to three weeks in the pupal stage, second-generation adults emerge, peaking about the middle of August. Second-generation larvae cause most of the damage. The same infestation cycle is repeated, with the pupa overwintering until the next spring (15).

Climatic conditions influence the activities of the codling moth. Temperature, which drives the degree day model, is the most important of the climatic factors, but humidity, rainfall and winds are also important (4, 23).

Damage: Fruit injury caused by codling moth is of two types. A larva may make a deep entry to the

center of the fruit and feed on seeds. Brown frass can usually be seen extruding from the entry hole. A sting is a shallow entry where the larva does some feeding but does not gain entry into the fruit (14).

Monitoring: Monitor with pheromone traps to biofix the start of adult flight and initiate degree day accumulations for determining the timing of insecticide applications. Fruit should always be visually inspected, especially in the upper canopy and along orchard borders in conjunction with trapping (4, 23).

Cultural/Biological Controls: Carpovirusine, a biological insecticide based on *Cydia pomonella* granulosis virus has been registered in Michigan since 2002. It is an effective tool for managing resistance to existing insecticides and for controlling the existing codling moth population (21). Encouraging data from research trials in two Michigan orchards indicate that *Mastrus ridibundus*, a larval parasitoid of CM, may have significant impact on CM populations (22).

Autocidal Control: Pheromone-based mating disruption can be an effective tactic for managing low-moderate density populations. The disruption treatment is often combined with companion insecticide sprays to reduce pest densities (25).

Chemical Controls: Codling moth has traditionally been controlled with organophosphate (OP) insecticides. Rotation of OPs with other materials plays an important part in resistance management. Loss of OPs will result in increased use of synthetic pyrethroids that can lead to the disruption of current IPM programs (15). Codling moth control requires careful monitoring and timing of insecticide applications to coincide with the targeted life stage being treated. Once larvae have tunneled into the fruit, insecticides cannot affect them (4).

<u>The following products are registered in Michigan for codling moth control:</u>

Azinphos-methyl (Guthion): The most widely used insecticide for controlling codling moth. It is highly effective with up to 2 weeks residual activity depending on weather but resistance has been documented in Michigan. Cannot be used in U-Pick plantings (15, 25).

Phosmet (Imidan): Second most widely used insecticide for codling moth control. It is effective for control but has shorter residual than Guthion, so more applications are required. It has a shorter PHI than azinphos-methyl thus it is often used late in the season. It is easier on beneficial insects than other OPs, however, resistance to phosmet is suspected (15, 25).

Diazinon: Residual activity of 10 to 14 days (1).

Carbaryl (Sevin): Effective if used at high rates but has short residual and is toxic to beneficial insects and mites (15).

Methomyl (Lannate): Effective at high rates but has short residual, is harmful to beneficial insects and mites and disrupts IPM programs. Cannot be used in U-Pick plantings (15).

Esfenvalerate (Asana): It has a short residual, is harmful to beneficial insects and mites and resistance will occur with repeated use (15).

Fenpropathrin (Danitol): Has a short residual, is harmful to beneficial insects and mites and resistance will occur with repeated use (15).

Tebufenozide (Confirm): It is effective if pest pressure is low to moderate. High rate and multiple applications are required. Product cost is high (15).

Spinosad (SpinTor): It is effective if pest pressure is low to moderate. High rate and multiple applications are required and it is very expensive (15).

Pyriproxifen (Esteem): Used largely as an ovicide and is only moderately effective. Timing is critical. It can only be used on the first generation because of a long pre-harvest interval. The cost is prohibitive (15).

Indoxacarb (Avaunt): Questionable efficacy and short residual (15).

Methoxyfenozide (Intrepid): Effective if used at the high rate and if pest pressure is low to moderate. It is more effective than tebufenozide (15, 25).

Acetamiprid (Assail): Good control. Some indication that repeated use may cause mite flaring (15, 25).

Thiacloprid (Calypso): Good control. Limited data on performance in large plots (15, 25).

Oriental Fruit Moth

Grapholitha molesta (Busck)

Oriental Fruit Moth (OFM) is generally considered a more serious pest of peach than of apple. In recent

years, however, it has become a major pest of apples in Michigan and in the eastern United States. In southwest Michigan, the incidence of OFM infestations in apples appears to be similar to the incidence of codling moth infestations (15).

Life Cycle: There are three full generations and occasionally a partial fourth generation of OFM in Michigan. The moths overwinter as larvae in cocoons on trees, ground debris and structures. Pupation begins in mid-March and adults emerge for about two months, peaking about the last week of May or early June. Adults are small, grayish brown moths with wings silvery on the undersurface and figured with light, wavy lines above. Succeeding generations develop from egg to adult in about six weeks, with a minimum of 24 days during hot weather. Second-generation larvae emerge about July 1 and attack both twigs and fruit. Third-generation adults emerge in early to mid-August and may continue until mid-September. The majority of third-generation larvae mature, spin cocoons and remain in the cocoons to overwinter. In very warm seasons, a few may pupate and emerge as adults that produce a few eggs and larvae late in the season (4).

Damage: Newly hatched larvae are white with black heads and about 1.4 mm in length. Mature larvae have brownish heads and pink bodies measuring 10-11 mm long. They also have an anal comb located ventrally at the posterior end of the abdomen. The presence of an anal comb (see picture above) distinguishes this pest from codling moth larvae. The first generation OFM larvae bore into apple shoots. Subsequent generations feed within the apple and make the fruit unmarketable. The last generation is especially problematic. Larvae hatch near or during harvest and are a major cause of wormy fruit. Codling moth and Oriental fruit moth larvae cause similar types of fruit damage. Both will enter fruit from either the calyx end or from the side of the apple. Codling moth feeds in the center of the fruit on flesh and seeds. Oriental fruit moth generally feeds on flesh away from the center, but can occasionally feed at the center as well (4, 15, 23).

Monitoring: Monitor with pheromone traps to biofix the start of adult flight and initiate degree day accumulations for determining the timing of insecticide applications. Fruit should always be visually inspected, especially in the upper canopy and along orchard borders in conjunction with trapping (4, 23).

Cultural/Biological Controls: The braconid wasp *Macrocentrus ancylivorus* is an important parasite that destroys many of the first-and second-generation larvae (4).

Autocidal Control: Pheromone mating disruption is an effective control tool for OFM (23).

Chemical Controls: The last generation of Oriental fruit moth attacks fruit late in the season at a time when insecticides often are not being applied for pest control. OFM is generally considered more difficult to control than codling moth, especially with organophosphates. Growers who wonder why they are having trouble controlling codling moth may be surprised to learn they are instead mismanaging infestations of OFM (4).

The following products are registered in Michigan for OFM control:

Azinphos-methyl (Guthion): 10 to 14 day residual activity and low toxicity to predaceous mites (1). Cannot be used in U-Pick orchards (25).

Phosmet (Imidan): Good broad-spectrum control (1).

Diazinon (Diazinon): Residual activity of 10 to 14 days (1).

Methomyl (Lannate): Primarily effective as a contact insecticide, though some systemic activity is also evident. Residues are only effective for 3-7 days so timing is important. It is highly toxic to mite predators, bees and fish, and may be phytotoxic to some apple cultivars. Cannot be used in U-pick orchards (1).

Carbaryl (Sevin): Effective if used at high rates. It has short residual and is highly toxic to beneficial insects (15).

Esfenvalerate (Asana): It has short residual. Post-bloom use may upset mite management programs by harming beneficial mites and insects (15).

Fenpropathrin (Danitol): To reduce the risk of resistance developing and to conserve natural enemies, restrict post-bloom applications to a single spray then switch to a different insecticide class. Has a short residual (1).

Methoxyfenozide (Intrepid): It is active against larvae and has sub-lethal effects on adults. It is an insect growth regulator that mimics hormone-induced molting and metamorphosis (1, 15, 25).

Indoxacarb (Avaunt): Rain-fast but is only moderately effective and thorough coverage is critical (1, 25).

Spinosad (SpinTor): Is moderately active against larvae, providing 7 to 14 days of residual control. It can be toxic to bees (1, 25).

Acetamiprid (Assail): Provides very good control of larvae (25).

Thiacloprid (Calypso): Provides very good control of larvae (25).

Plum Curculio

Conotrachelus nenuphar (Herbst)

Plum curculio is one of the most important insects attacking fruit trees and one of the most difficult to control. Without control measures, 50-90% of the apple crop can be damaged (15).

Life Cycle: Plum curculio adult beetles migrate from their winter hibernation quarters into orchards when temperature and moisture conditions are favorable in the spring around bloom time. They are small (4-6 mm long), rough, snout beetles mottled with black, gray and brown. Peak activity and the critical time for control is during a two to three week period beginning at petal-fall. The adults do not like strong light and prefer the dense shade of the tree's inner canopy. After mating, the female deposits eggs into the newly developing fruit, leaving a crescent-shaped scar. The incubation period for the eggs is about one week. The young larvae are white with a brown head, curved and legless, eventually growing to about 6-9 mm. They burrow throughout the apple creating brown trails. Many infested fruit fall from the tree in June. After several weeks the larvae emerge from the apples and fall to the ground where they pupate. Adults emerge from the soil in late summer and feed on the surface of maturing apples until cold weather forces them into hibernation (4, 15).

Damage: The wounds resulting from spring egg laying by the beetles form crescent-shaped scars on the fruit or bumps that protrude from the fruit at harvest. Infested fruit may be knobby, gnarled and scarred at harvest with internal injury caused by the larvae's burrowing into the fruit. Premature fruit drop during June or later in the season is a result of larval activity within the fruit, or from adults feeding on the fruit. Feeding punctures made by the beetles in the fall just prior to hibernation are characterized by a small hole in the skin of the apple with a hollowed out circular cavity in the flesh that extends a few millimeters on each side of the opening. Early season varieties are most susceptible to both feeding and oviposition damage (4).

Monitoring: Plum curculio activity can be monitored by visually inspecting fruit for signs of feeding or egg-laying, concentrating on trees adjacent to hedgerows and woodlands. Where curculio pressure is known to be high, multiple fruit per tree should be monitored as often as daily. Beating trays can be used to determine plum curculio pressure. Pyramid or screen traps baited with plant volatiles and an aggregate pheromone can also be used to monitor plum curculio activity.

Cultural/Biological Controls: There are no viable options for commercial growers.

Chemical Controls: Petal-fall sprays and first and second cover sprays are directed at the adult during

the egg-laying period. Once the fruit is exposed, the females lay many eggs in a short time and cause considerable damage. If the weather is cool at bloom time and petal fall, the beetles may not leave hibernation quarters and move into the fruit trees until first cover (4). Under these conditions petal fall applications may not be fully effective and a first cover application and possibly another application at second cover will be needed. Organophosphates are the first option for most growers and are applied at least 65 days before harvest (15).

<u>The following products are registered and recommended in Michigan for plum curculio control:</u>

Azinphos-methyl (Guthion): Most widely used insecticide for control of plum curculio. It is highly effective with up to 2 weeks of residual activity. Cannot be used in U-Pick orchards (15, 25).

Phosmet (Imidan): Second most widely used material for plum curculio control (15).

Diazinon (Diazinon): good control, residual activity of 10 to 14 days (1).

Esfenvalerate (Asana): Short residual so multiple applications are required. It is an effective option to organophsphates but sprays are made after bloom and pyrethroid use at this time is likely to upset mite management programs by destroying beneficial insects and mites (15).

Indoxacarb (Avaunt): Very good efficacy. A primary reduced risk option for curculio control (15, 25).

Thiamethoxam (Actara): Very good efficacy but only one application at the high rate of 4.5-5.5 ozs/acre can be made (15, 25).

Acetamiprid (Assail): Very good control. A primary OP replacement for curculio control (1).

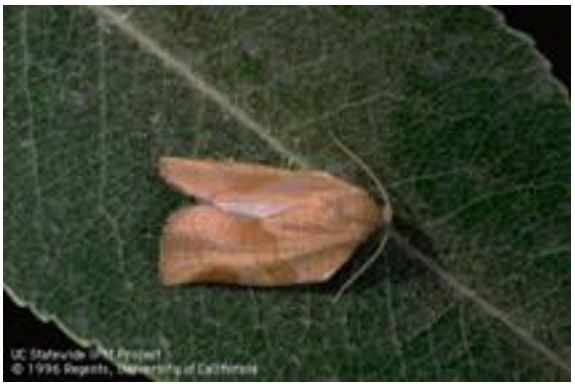
Thiacloprid (Calypso): Very good control (1).

Fenpropathrin (Danitol): Good control (1).

Permethrin (Ambush or Pounce): Good control but can’t be used after petal fall. It can cause mite outbreaks as a result of disrupting natural predators (1).

Obliquebanded Leafroller

Choristoneura rosaceana (Harris)



Leafrollers are a complex of species comprised of the obliquebanded leafroller, redbanded leafroller, variegated leafroller, tufted apple budmoth and eyespotted budmoth. However, obliquebanded leafroller is the key leafroller pest in Michigan. The obliquebanded leafroller (OBLR) is becoming more of a concern in apple growing regions because of resistance development to several key insecticides, including OPs (1, 15).

Life Cycle: There are two complete generations per year in Michigan. OBLR overwinters as an immature larva. Larvae begin feeding inside bud clusters and on floral parts prior to bloom and feed on developing fruit and leaves after petal fall. The full grown larvae are large (20-30 mm long), with green bodies and brown to black heads. When the leaves become larger, the larvae web the leaves into tubular chambers. Larvae mature in late May and June. Pupation occurs within the feeding site and lasts about 10-12 days. Moths emerge for about a month beginning in early to mid-June with peak activity in late June. The moths are banded with tan to chocolate-brown scales. Females are much larger than the males (24-30 mm vs. 17-23 mm). Eggs are laid shortly after mating and hatch in 10-12 days. The first generation larvae, present in late June into August, feed on water sprouts and fruit. Pupation takes place in their final feeding sites. Adults are on the wing from mid-August to late September. The incubation period and activity of the second-generation larvae are the same as those of the first generation. Most of the larvae will overwinter in the apple tree (4, 15).

Damage: Overwintering larvae feed on floral parts during bloom and on developing fruit after petal fall. The larvae gouge deeply into young fruit as they feed. Many fruit damaged at this time drop from the tree before harvest. In late July, larvae of the summer generation can be found feeding actively on growing terminals and on fruit. They prefer to feed underneath a protective covering of leaves or within a fruit cluster. Summer feeding injury leaves the fruit unmarketable for the fresh market and can result in over 50% crop loss (4, 15, 23).

Monitoring: Terminals should be checked for overwintering larvae after petal fall. When larvae are found in more than 1-2% of the shoots, summer controls likely will be needed. Pheromone traps can be used as an indicator of adult leafroller activity and to time treatment decisions. Catches of less than 20 moths for an entire flight period generally means this pest is not present at problematic levels (14, 23).

Cultural/Biological Controls: *Bacillus thuringiensis* (Dipel, Javelin, etc.) can be an effective control for leafroller complex. However, B.t. is temperature sensitive; it is often too cool in Michigan to allow

for good efficacy on overwintering larvae. Additionally, it has a short residual so multiple applications are required. Several parasitoids attack leafroller larvae and can provide up to 60% mortality if insecticides are used judiciously (15, 25).

Autocidal Controls: Pheromone-based mating disruption can be used as a supplement to insecticidal control.

Chemical Controls: Controls are applied both pre- and post-bloom. Broad-spectrum insecticides will control this pest in larval and adult stages. Sprays applied at pink stage or petal fall will prevent damage from the overwintering larvae. Timing of summer sprays should be based on pheromone trap catches and use of degree-day models. In some areas, this pest has become resistant to some pesticides, including organophosphates, so chemicals with a different mode of action may be required to control it (4).

<u>The following products are registered in Michigan for obliquebanded leafroller control:</u>

Azinphos-methyl (Guthion): Poor to fair control depending on the degree of resistance in each apple growing area of the state. Cannot be used in U-Pick orchards (15, 25).

Phosmet (Imidan): Poor to fair control depending on the degree of resistance in each apple growing area of the state (15).

Methomyl (Lannate): Short residual, many applications required for season-long control (15).

Esfenvalerate (Asana): Short residual so many applications are required for season-long control. Post-bloom use may upset mite management programs by destroying beneficial mites and insects (15).
Spinosad (SpinTor): Good efficacy at high rate. The product cost is high (15).

Tebufenozide (Confirm): Good efficacy at a high rate but slower acting than traditional materials (15).

Methoxyfenozide (Intrepid): Good activity, especially at high rates. It is more effective than tebufenozide (15).

Permethrin (Ambush or Pounce): Good control but can’t be used after petal fall. Can cause mite outbreaks as a result of disrupting natural predators (15).

Fenpropathrin (Danitol): Good control (1).

Apple Maggot

Rhagoletis pomonella (Walsh)

Life Cycle: Adult flies begin emerging from overwintering pupae in late June (Southern Michigan) or early July (Northern Michigan). Females are about 5.8 mm long, have a black thorax marked with a dorsal white spot and broad wings that are clear at the base with four dark cross-bands traversing each wing. The male is smaller than the female. Flies begin to lay eggs just under the apple skin 8 to 10 days after emergence. Eggs hatch in less than a week and the maggots tunnel through the apple, leaving a characteristic brown trail. The mature maggots are about 8 mm long and 2 mm wide, white to pinkish, leggless, pointed at the head end with dark hook-shaped, continuous jaws. They leave the fruit and enter the soil for pupation. Most pupae remain in the soil until the following summer. However, a few individuals do not emerge until the second summer. These are not of much significance to growers who maintain control every year, but they might be of importance in an orchard where the pest was not closely monitored (4).

Damage: The apple maggot causes two forms of injury. The flesh surrounding the puncture where eggs are deposited fails to grow with the rest of the apple, causing the surface to be dimpled and lumpy. When the larvae feed and move through the fruit, they leave a characteristic brown trail through the flesh of the apple that can readily be seen when the fruit is cut open. When several maggots are in a fruit, the interior tissues may break down and depressions and discoloration may be visible from the outside. Apples injured early in the season usually drop prematurely (4).

Monitoring: Traps should be set in mid-June and first treatments should be made 7- 10 days after the first fly is trapped. If using insecticides that require ingestion, treat immediately upon fly capture (14, 23).

Cultural/Biological Controls: There are no viable options for commercial growers.

Chemical Controls: Due to zero tolerance, effective controls are essential. The only practical means to control the apple maggot is to kill flies before the females deposit eggs. Organophosphates are the most often used control for the apple maggot (4, 23).

The following products are registered in Michigan for apple maggot control:

Azinphos-methyl (Guthion): Most widely used insecticide for control of apple maggot. It is highly effective with up to two weeks of residual activity. Cannot be used in U-Pick orchards (15, 25).

Phosmet (Imidan): Second most widely used material for apple maggot control. It is effective but requires more applications than Guthion because of shorter residual (15).

Diazinon (Diazinon): Provides good control and has residual activity of 10 to 14 days (1).

Methomyl (Lannate): Residues remain effective for about 3-7 days so timing is important. It is highly toxic to mite predators and somewhat phytotoxic to certain apple varieties. Methomyl may not be used in U-pick orchards (1).

Carbaryl (Sevin): It has short residual and is less effective than organophosphates (15).

Esfenvalerate (Asana): Short residual so multiple applications are required. Post-bloom use may upset mite management programs by destroying beneficial mites and insects (15).

Fenpropathrin (Danitol): To reduce the risk of resistance developing to this product and to conserve natural enemies, restrict post-bloom applications to a single spray then switch to a different chemical class (1).

Spinosad (SpinTor): Provides 7 to 14 days of residual control (1).

Kaolin (Surround): Provides excellent control but good coverage is critical (1).

Acetamiprid (Assail): Promising new material that appears to provide good control (25).

Thiacloprid (Calypso): Promising new material that appears to provide good control (25).

European Red Mite

Panonychus ulmi (Koch)


Life Cycle: The European red mite passes the winter in the egg stage on rough bark of apple trees. Winter eggs are usually found near buds, fruit spurs, and in the forks of branches. Eggs begin hatching at the tight cluster stage of bud development and continue until the end of bloom. The small, bright red or orange larvae begin feeding on the leaves at once. After several molts, the adults mate and begin summer egg deposition. The first summer eggs are deposited by petal fall or first cover and develop to adults in about three weeks. Subsequent summer generations take 18 days from egg to adult. Overwintering egg deposition begins in mid-August and continues until cold weather. European red mites are able to cling tenaciously to leaf surfaces and, unlike the common red mite, are not easily washed off by rains or heavy sprays. (4).

Damage: Mites feed by inserting their mouthparts into the leaf cells and sucking out the contents, including chlorophyll. This causes leaves to turn bronze colored, and severe infestation can cause defoliation. The leaves can recover if the mites are destroyed before the leaves are badly damaged. The mites do not feed on the fruit itself, but the fruit is indirectly affected. Foliage injury reduces the vigor of the tree and thus reduces the size of the apples. The most serious injury occurs in early summer, when trees are producing fruit and buds for the following season. Bronzing on moderately to heavily infested trees (30 mites or more per leaf) causes trees to produce fewer and less vigorous buds for the following year. Thin leaved apple varieties such as Delicious, Rome and Northern Spy are more susceptible to mites (4, 14).

Monitoring: Monitoring for summer populations consists of examining leaf samples from several locations using 50% spur leaves and 50% shoot leaves. Treatment decisions are based on the presence of threshold numbers of European red mites and the number of predator mites (4).

Cultural/Biological Controls: Good biological control of European red mite and the two-spotted spider mite is obtained by conserving predators. In commercial apple orchards this is done through the judicious use of selective insecticide and fungicides that are soft on predatory mites (4).

Chemical Controls: The following products are registered in Michigan for European red mite control: *Avermectin* (Agri-Mek), *dicofol* (Kelthane), *bifenazate* (Acramite), *clofentezine* (Apollo), *fenpropathrin* (Danitol), *fatty acids* (MPEDE), *pyridaben* (Pyramite), *hexythiazox* (Savey),*fenbutatin-oxide* (Vendex), *omaxyl* (Vydate) and *etoxazole* (Zeal) (1).

Alternative Controls: "Superior Oil" (Sun Oil, others) can be used as a preventive European red mite

control (23).

Two-spotted Spider Mite
Tetranychus urticae (Koch)

Life Cycle: Full-grown female mites and some immature mites overwinter on the trunk of the tree or in protected places on the ground. In the spring, the mites leave their hibernation sites and crawl to the ground, where they feed on weeds and grasses. The first eggs can usually be found about the pink stage. In warm weather, these hatch in five to eight days. A complete generation from egg to adult may require no more than three weeks. Five to nine generations occur in the orchard each season depending on the weather. In mid- to late summer, when drought and other factors reduce the food quality of weeds and grasses, mites move up the tree trunks or infest the leaves of low hanging branches and quickly spread upward and into the interior of the tree. They suck juices from the leaves and spin fine silken webs around them. In the fall, adults find hibernation places either on the tree bark or on the ground under the tree (4).

Damage: Two-spotted spider mite injury is similar to that caused by the European red mite, however, there is much more webbing with two-spotted spider mites than with similar populations of European red mites (4).

Monitoring: Monitoring for summer populations consists of examining leaf samples from several locations using 50% spur leaves and 50% shoot leaves. Treatment decisions are based on the presence of threshold numbers of two-spotted spider mites and the number of predator mites (4, 23).

Chemical Controls: These mites are controlled with summer applications of miticides. The following products are registered in Michigan for two-spotted spider mite control: *Dicofol* (Kelthane) and *Fenbutatin-oxide* (Vendex)(4).

SECONDARY APPLE INSECT AND MITE PESTS

The insect and mite pests covered above are the most serious economic pests of apples in Michigan but are not the only pests that need to be controlled in order to produce marketable fruit. More than a dozen others have the potential to cause minor to serious damage if left uncontrolled. However, the currently registered pesticides applied as cover sprays for the serious pests also protect trees and fruit from damage by many of the secondary pests. Should any of the major insecticides or miticides be withdrawn from the market, it is possible that any or all of the secondary pests would soon become primary pests. Below is a listing of the secondary pests and their damage severity ranking without the use of pest control products (15).

- San Jose scale: Moderate
- Spotted tentiform leafminer: Moderate
- Rosy apple aphid: Moderate
- Tarnished plantbug: Minor to Serious
- Green fruitworm: Moderate
- White apple leafhopper: Moderate
- Potato leafhopper: Moderate
- Apple rust mite: Moderate
- Green apple aphid or species: Moderate
- Tufted apple budmoth: Moderate
- Japanese beetle: Minor to Serious
- Dogwood borer and other borers: Moderate

INSECTICIDE PROFILES

Bearing acres in 2001 were 44,000
Bearing acres in 1999 were 52,500

Acetamiprid
(neonicotinoid)

Formulations: Assail 70 WP.
Pests controlled: Codling moth, oriental fruit moth, plum curculio, tentiform leafminer, aphids, leafhoppers (1).
% Crop acreage treated: Not listed in the NASS data (2003 was the first season it was used) (7).
Type of Application: Ground application (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Petal-fall through the growing season (1).
REI: 12 hrs (16).
PHI: 7 days (16).

Use in IPM: Reduced risk and potential OP replacement material (25).
Efficacy issues: Highly effective against several key and secondary pests of apple (25).

Azadirachtin

(botanical extracts from the Neem tree of India)

Formulations: Ecozin, AzaDirect, Agro-Neem and Neemix.
Pests controlled: Aphids, leafhopper, leafrollers, leafminers, codling moth, thrips and many others (16).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: See label for timing of specific pest. Because of short residual life, it may need to be re-applied every 5-10 days if pest populations persist (1).
REI: 12 hrs (16).
PHI: 0 days (1).
Use in IPM: AzaDirect and Neemix are listed by the Organic Materials Review Institute (OMRI) for use in organic production. Toxic to fish and aquatic invertebrates, and to bees exposed to direct treatment or residues on blooming crops or weeds (1).
Efficacy Issues: The recommended tank water pH range is between 5.5 and 6.5 (1)

Azinphos-methyl

(organophosphate)

Formulations: Guthion 50W. Restricted Use Pesticide.
Pests controlled: Nonresistant oblique banded leafroller, plum curculio, oriental fruit moth, codling moth, potato leafhopper, rose chafer, tufted apple budmoth and apple maggot, Japanese beetle (1).
% Crop acreage treated (NASS): 87% in 2001, 92% in 1999 (7).
Type of application: Ground application (16).
MI average rate per application (NASS): 0.63 lbs ai/A (2001), 0.7 lbs ai/A (1999) (7). Maximum yearly amount allowed is 9 lbs/A per season (16).
Number of applications (NASS): 3.6 times per season in 2001, 3.5 times per season in 1999 (7).
Timing: Late April/mid-May, mid-June/mid-July, and August (1).
REI: 2-21 days (16).
PHI: 14 days, or 21-day PHI if the last application is greater than 2 lbs of Guthion 50WP per acre (1).
Use in IPM: Applications made at rates above 2 lbs per acre can only be made in conjunction with an IPM program (16).
Efficacy issues: Highly effective for codling moth, oriental fruit moth, plum curculio, and apple maggot

with up to 2 weeks of residual activity (15). Limited control of insects that have resistance to organophosphates, like the white apple leafhopper, spotted tentiform leafminer, obliquebanded leafroller and some populations of codling moth. It is known to be of general low toxicity to predacious mites that are important as biological control agents for mite pests of fruit (1).

The baby food industry allows growers to use azinphos-methyl but only with a 45 day PHI (11).

Bacillus thuringiensis
(biological)

Formulations: Dipel, Javelin, Agree, Biobit, Deliver and Crymax.
Pests controlled: Controls lepidopteran larvae but must be ingested by susceptible larvae to be effective (1).
% Crop acreage treated (NASS): 14% in 2001, 42% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): Not included in NASS data (7).
Number of applications (NASS): 1.9 per season in 2001, 2.4 per season in 1999 (7).
Timing: Time applications for early egg hatch; two or three applications are generally required. (1).
REI: 4 hours (16).
PHI: 0 days (16).
Use in IPM: B.t.s can be used during bloom and do not impact most natural enemies (1).
Efficacy issues: Efficacy is temperature dependent. B.t.s are most effective when applied during warm weather with daily highs in the 70s (1).

Carbaryl
(carbamate)

Formulations: Sevin 50 WP, Sevin 80S, Sevin XLR Plus.
Pests controlled: Codling moth, rose chafer, woolly apple aphid, apple maggot, Oriental fruit moth, Japanese beetle, white apple leafhopper, potato leafhopper and Japanese beetle (1).
% Crop acreage treated (NASS): 39% in 2001, 32% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.9 lbs ai/A in 2001, 0.72 lbs ai/A in 1999 (7).
Number of applications (NASS): 1.5 times per season in 2001, 1.1 times per season in 1999 (7).
Timing: Repeat applications as necessary up to a total of 8 times (including thinning sprays) but not more often than once every 14 days (16).
REI: 12 hours (16).
PHI: 3 days (16).

Use in IPM: Toxic to beneficial insects and mites and disruptive to established IPM programs. Sevin is a fruit-thinning agent if used in apples within 30 days of full bloom (1).
Efficacy issues: The low PHI makes Sevin an effective tool for near-harvest pest control (1).

The baby food industry allows the use of carbaryl as a thinning agent only (11).

Chlorpyrifos
(organophosphate)

Formulations: Lorsban 4E. Restricted Use Pesticide.
Pests controlled: Dogwood borer, San Jose scale, rosy apple aphid, green fruitworm (1).
% Crop acreage treated (NASS): 61% in 2001, 63% in 1999 (7).
Type of application: Trunk spray or foliar application, pre-bloom only (1).
MI average rate per application (NASS): 1.02 lbs ai/A in 2001, 0.85 lbs ai/A in 1999 (7).
Number of applications (NASS): 1.2 times per season in 2001, 1.5 times per season in 1999 (7).
Timing: Pre-bloom only (1).
REI: 4 days (1)
PHI: Pre-bloom use only (1).

Diazinon
(organophosphate)

Formulations: Diazinon 50 W. Restricted Use Pesticide.
Pests controlled: Scales, mites, aphids, codling moth, leafrollers, leafhoppers (16).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: See label for timing for specific insects.
REI: 24 hrs (16).
PHI: 21 days (16).
Efficacy Issues: It will not control OP resistant strains of white apple leafhopper, spotted tentiform leafminer or obliquebanded leafroller, which are common in Michigan (1).

Endosulfan
(organochlorine)

Formulations: Endosulfan 50WP, Phaser 3EC, Thiodan 3 EC and 50 WP (1).
Pests controlled: Spotted tentiform leaf miner, aphids, tarnished plantbug, and green fruitworm (1).
% Crop acreage treated (NASS): 14% in 2001, 10% in 1999 (7).
Type of application: Ground (16).

MI average rate per application (NASS): 0.91 lbs ai/A in 2001, 0.77 lbs ai/A in 1999 (7). Do not exceed a maximum of 3 lbs. ai/A per year (16).
Number of applications (NASS): 1.1 times per season in 2001, 1.5 times per season in 1999 (7). No more than two applications allowed during the fruiting season and no more than 3 applications per year (16).
Timing: *Tarnished plantbug, green fruitworm and rosy apple aphid*: Apply at pink and/or petal fall (16). *Tentiform leafminer:* Make first application as soon as moth flight begins. A second application should be made 10 days later (16).
REI: 24 hours (16).
PHI: 21 day (16).
Use in IPM: *Zetzellia mali*, a predatory mite is susceptible to endosulfan (14).
Efficacy issues: Post-harvest sprays of endosulfan reduce late season infestations and there are no restrictions for post-harvest use of the product (1).

Esfenvalerate
(pyrethroid)

Formulations: Asana XL 0.66 EC. Restricted Use Pesticide.
Pests controlled: Spotted tentiform leaf miner, tarnished plant bug, green fruitworm, oblique banded leafroller and others, plum curculio, codling moth, green apple aphid, apple maggot, oriental fruit moth, tufted apple budmoth and Japanese beetle (1).
% Crop treated (NASS): 43% in 2001, 50% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.03 lb ai/A in 2001, 0.04 lb ai/A in 1999 (7). Do not apply more than 0.5 lb ai/acre/season (16).
Number of applications (NASS): 1.3 times per season in 2001, 1.3 times per season in 1999 (7).
Timing: It is compatible with oil and can be used for pre-bloom insect control as well as timing appropriate to the insect to be controlled (1).
REI: 12 hours (16).
PHI: 21 days (16).
Use in IPM: Highly toxic to mite predators and should be used carefully to prevent mite population buildup (1).
Efficacy issues: Should be applied before eggs hatch (1).

Fenpropathrin
(pyrethroid)

Formulations: Danitol 2.4 EC. Restricted Use Pesticide.
Pests controlled: a broad spectrum of insects and mites (1).
% Crop Acreage treated (NASS): 38% in 2001 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.22 lbs ai/A in 2001 (7).
Number of applications (NASS): 1.5 applications per season in 2001 (7).
Timing: Begin applications at delayed dormant through first cover as common to the production area and the target pest (16). To reduce the risk of resistance developing and to conserve natural enemies, restrict post-bloom applications to a single spray (1).
REI: 24 hrs (16).
PHI: 14 days (16).
Use in IPM: Successive sprays against the same pest should be alternated with a different insecticide class. Highly toxic to mite predators (1).

Formetanate hydrochloride
(carbamate)

Formulations: Carzol 92SP.
Pests controlled: Spotted tentiform leafminer, European red and two spotted spider mites, tarnished plantbug and white apple leafhopper (1).
% Crop acreage treated (NASS): 12% in 1991, 15% in 1993, 5% in 1995 and 1% in 1997. Carzol does not appear on the NASS chemical use survey for 1999 or 2001 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 1.05 lbs ai/A in 1991, 1.07 lbs ai/A in 1993, 0.8 lb ai/A in 1995 and 0.79 in 1997. Carzol does not appear on the NASS chemical use survey for 1999 or 2001 (7).
Number of applications (NASS): 1.3 times per season in 1991, 1.3 times per season in 1993, 1.4 times per season in 1995, 1.4 times per season in 1997. Carzol does not appear on the NASS chemical use survey for 1999 or 2001 (7).
Timing: No applications can be made after petal fall (16).
REI: 4-16 days depending on the task preformed (16).
PHI: Do not apply after petal fall (1).
Use in IPM: Highly toxic to bees and mite predators (1).
Efficacy issues: Most effective for controlling immature and adult forms of European red and two-spotted spider mites (1).

Imidacloprid
(chloronicotinyl)

Formulations: Provado 1.6 EC.
Pests controlled: Organophosphate resistant white apple leafhopper and spotted tentiform leaf miner, potato leafhopper, aphids (1).
% Crop acreage treated: 49% in 2001, 67% in 1999, 42% in 1997 (7).
Type of application: ground (16).
MI average rate per application (NASS): 0.06 lb ai/A in 2001, 0.05 lb ai/A in 1999 (7).
Number of applications: 1.4 times per season in 2001, 1.6 times per season in 1999(7).
Timing: Must be applied at early petal fall for effective timing on the first generation of spotted tentiform leafminer sap-feeding larvae (1).
REI: 12 hours (16).
PHI: 7 days (16).
Use in IPM: Because most of Provado's surface residue is quickly absorbed into the plant, negative impact on natural enemies is minimized (1).

Indoxacarb
(oxadiazine)

Formulations: Avaunt 30 WG.
Pests controlled: Plum curculio; also active against codling moth, oriental fruit moth, leafrollers, leafhoppers and plant bugs (1).
% Crop Acreage treated (NASS): Area treated was less than 1% in 2001 (7).
Type of application: Ground (16).
MI average rate per application: 0.09 lb ai/A (7).
Number of applications: 1.2 applications per season in 2001 (7).
Timing: Petal fall through the growing season (25).
REI: 12 hrs (16).
PHI: 28 days (16).
Use in IPM: Novel mode of action (25).
Efficacy Issues: Thorough coverage is critical for good pest control. Good rain fastness characteristics (25).

Kaolin
(clay mineral)

Formulations: Surround WP.
Pests controlled: Green fruit worm, leafrollers, obliquebanded leafroller, leafhoppers, apple maggot, codling moth (16).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Begin sprays before pest becomes apparent. Multiple applications are typically needed to attain initial coverage, as well as to compensate for actively growing plant tissue and to respond to wash-off from rain or excessive wind (1).
REI: 4 hrs (16).
PHI: 0 days (1).
Use in IPM: Surround creates a protective barrier between the plant and the pest that reduces host recognition of the pest and prevents normal movement and damaging activity. The material is abrasive to insect/mite body parts as well, and may cause irritation or mortality (1).
Efficacy Issues: Complete coverage of the plant and multiple applications are critical (1).

Lambda cyhalothrin
(pyrethroid)

Formulations: Warrior.
Pests controlled: Broad spectrum control of sucking and chewing insects, including leafrollers, leafhoppers, plum curculio, codling moth and oriental fruitworm (1).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Apply when insects reach economic thresholds, at intervals of 7 or more days (16).
REI: 24 hrs (16)
PHI: 14 days (16).
Use in IPM: Highly toxic to mite predators and should be used carefully to prevent mite population buildup (16).
Efficacy Issues: Has unique micorencapsulated formulation (Zeon Technology) that protects the foliar residue from UV degradation so as to enhance the compound's residual activity (16).

Methomyl
(carbamate)

Formulations: Lannate 90SP.
Pests controlled: Oblique banded leafroller, other leafrollers, aphids, tarnished plantbug, green fruitworm, white apple leafhopper, potato leafhopper, spotted tentiform leaf miner, Oriental fruit moth, codling moth, rose chafer, tufted apple budmoth and apple maggot (1).
% Crop acreage treated (NASS): 32% in 2001, 17% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.66 lbs ai/A in 2001, 0.72 lbs ai/A in 1999 (7). Do not use more than 4.5 lbs ai per acre per crop (16).
Number of applications (NASS): 1.3 times per season in 2001, 1.1 times per season in 1999 (7). Do not make more than 5 applications per crop (16).
Timing: Pink - aphids, tarnished plantbug, green fruitworm, oblique banded leafroller, **petal fall** - aphids, white apple leafhopper, potato leafhopper, spotted tentiform leaf miner, oblique banded leafroller, other leafrollers; **second cover** - codling moth, tufted apple budmoth; **third cover** - codling moth, red-banded leafroller, green apple aphid, tufted apple budmoth, oblique banded leafroller, spotted tentiform leaf miner; **fourth cover** - apple maggot, codling moth; **fifth cover** - apple maggot, codling moth, red-banded leafroller, sensitive and resistant oblique-banded leafroller; **sixth through eighth cover** - aphids, apple maggot, codling moth, red-banded leafroller, spotted tentiform leaf miner, white apple leafhopper, oblique-banded leafroller.
REI: 72 hours (16).
PHI: 14 days (16).
Efficacy issues: Highly toxic to mite predators and should be used carefully to prevent mite population buildup. Toxic to fish and bees. Cannot be used in U-Pick orchards.
Remains effective for 3-7 days so timing is important (1).

Methoxyfenozide

(IGR - diacylhydrazine)

Formulations: Intrepid 2F.
Pests controlled: Codling moth, oriental fruit moth, leafrollers, tentiform leafminer, tufted apple budmoth (1).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Petal-fall through growing season (25).
REI: 4 hrs (16).
PHI: 14 days (16).
Use in IPM: Has both lethal and sub-lethal effects (25).
Efficacy Issues: Addition of an agricultural adjuvant is recommended to improve spray deposition (25).

Oxamyl
(carbamate)

Formulations: Vydate 2L. Restricted Use Pesticide.
Pests controlled: Mites, aphids, leafhoppers and leaf miner larvae (1).
% Crop acreage treated: 3% in 1999, not listed in the NASS data for 2001 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.84 lbs ai/A in 1999, not listed in the NASS data for 2001 (7).
Number of applications: 1 time per season in 1999, not listed in the NASS data for 2001 (7).
Timing: *Aphids*: Before bloom or when 50% of terminals are infested, *first brood spotted tentiform leafminer and when two or more larvae per leaf are present for second brood leafminer:* half inch green stage to early pink, *mites*: when 2-4 mites are present per leaf, *white apple leafhopper*: when pests are present in significant numbers (16).
REI: 48 hours (16).
PHI: 14 days (16).
Use in IPM: Highly toxic to bees, insect and mite predators (1).

Permethrin
(pyrethroid)

Formulations: Ambush 2 EC, Ambush 25 WP, Pounce 25 WP, Pounce 3.2 EC. Restricted Use Pesticide.
Pests controlled: Spotted tentiform leaf miner, tarnished plantbug, oblique-banded leafroller and other leafrollers, green fruitworm, plum curculio (1).
% Crop acreage treated (NASS): 35.7% In 2001, 21% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.12 lbs ai/A in 2001, 0.12 lbs ai/A in 1999 (7). Do not apply more than 0.6 ai per acre per season (16).
Number of applications (NASS): 1.1 times per season in 2001, 1.1 times per season in 1999 (7).
Timing: Tight cluster: spotted tentiform leaf miner; pink: tarnished plantbug, green fruitworm, oblique banded leafroller; petal fall: tarnished plantbug, plum curculio, leafrollers. Ambush and Pounce may not be applied after petal fall (1).
REI: 12 hours (16).
PHI: Do not apply after petal fall (1).
Use in IPM: The material is highly toxic to mite predators and should be used carefully to prevent mite population buildup (1).

Petroleum distillate
(Superior Oil)

Formulations: Biocover, Sunspray 6F (1).
Pests controlled: European red mite, San Jose scale, rosy apple aphid (1).
% Crop acreage treated (NASS): 26% in 2001, 36% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 15.3 lbs ai/A in 2001, 19.6 lbs ai/A in 1999 (7).
Number of applications (NASS): 1.2 times per season in 2001, 1.2 times per season in 1999 (7).
Timing: Tight cluster-Pre-Pink: European red mite, San Jose scale, rosy apple aphid (1).
REI: 4 hrs (1).
PHI: No residue if used according to recommendations (1).
Use in IPM: Superior oil is used preventatively and the 70-sec. oil remains on the tree long enough to kill the mites but not so long as to interfere with vital plant processes or oil-incompatible pesticides which may be applied later (1).

Phosmet
(organophosphate)

Formulations: Imidan 70 WP (1).
Pests controlled: Nonresistant oblique banded leafroller, plum curculio, oriental fruit moth, rose chafer, codling moth, potato leafhopper, Japanese beetle and apple maggot (1).
% Crop acreage treated (NASS): 76% in 2001, 74% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 1.2 lbs ai/A in 2001, 1.3 lbs ai/A in 1999 (7).
Number of applications (NASS): 2.2 times per season in 2001, 2.8 times per season in 1999 (7).
Timing: Pink - sensitive oblique banded leafroller; **petal fall** - plum curculio, oblique banded leafroller, other leafrollers, oriental fruit moth; **second cover** - codling moth, potato leafhopper; **fourth cover** - apple maggot, codling moth, oriental fruit moth, Japanese beetle; **fifth cover** - apple maggot, codling moth, red-banded leafroller, sensitive oblique-banded leafroller; **sixth-eighth cover** - apple maggot, codling moth, red-banded leafroller, oblique banded leafroller.
REI: 24 hours (1).
PHI: 7-8 days. See label for specifics (16). Contracted baby food acres allow up to 14 days PHI (11).
Use in IPM: Phosmet provides good broad-spectrum control of many apple pests and has low mammalian toxicity (1).
Efficacy issues: will not control resistant strains of white apple leafhopper, spotted tentiform leafminer and obliquebanded leafroller (1).

Pyriproxifen
(IGR)

Formulations: Esteem 35 WP.
Pests controlled: Codling moth, San Jose scale, spotted tentiform leafminer, rosy apple aphid.
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Restricted to 2 applications per year. Generally used at petal fall through second cover (25).
REI: 12 hrs (16).
PHI: 45 days (16).
Use in IPM: Unique mode of action makes it a good resistance management option. Active against codling moth eggs (25).
Efficacy Issues: No activity against adults (25).

Spinosad
(Naturalyte)

Formulations: Entrust
Pests controlled: leafrollers, codling moth, oriental fruit moth, green fruitworm, spotted tentiform leafminer (16).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: See label for specific insect timing.
REI: 4 hrs (16).
PHI: 7 days (16).
Use in IPM: Listed by the Organic Materials Review Institute (OMRI) for use in organic production. Provides 7-10 days of residual control depending on the target pest, but good coverage will increase consistency of crop protection. Good safety to many beneficials, but can be toxic to bees if contacted before sprays dry (1).
Efficacy Issues: The use of an adjuvant can enhance coverage and penetration of leaf surfaces (1).
Formulations: Spintor 2SC.
Pests controlled: Leafrollers, codling moth, oriental fruit moth, green fruit worm, and spotted tentiform leafminer (16).
% Crop Acreage treated: Not listed in the NASS data (7).

Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Timing varies by insect; see label for details. The primary route of entry into the target insects is through ingestion, although the product is also absorbed through the cuticle. Provides 7-14 days of protection but should be applied no more than 4 times/season (1).
REI: 4 hrs (16).
PHI: 7 days (16).
Use in IPM: SpinTor has good safety to many beneficials, but can be toxic to bees if contacted before sprays are dry (1).
Efficacy Issues: The use of a penetrating or silicone surfactant can enhance coverage and penetration of leaf surfaces (1).

Thiacloprid
(neonicotinoid)

Formulations: Calypso 480 SC.
Pests controlled: Codling moth, oriental fruitmoth, plum curculio, tentiform leafminer, aphids, leafhoppers (1).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Petal-fall through the growing season (25).
REI: 12 hrs (16).
PHI: 30 days (16).
Use in IPM: Reduced risk and potential OP replacement material (25).
Efficacy Issues: Highly effective against several key and secondary pests of apple (25).

Thiamethoxam
(neonicotinoid)

Formulations: Actara 25 WG.
Pests controlled: Plum curculio, tentiform leafminer, aphids, leafhoppers (1).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).

Timing: Can be used pre-bloom but primarily used at petal-fall and in the summer (25).
REI: 12 hrs (16).
PHI: 14 days; 35 day PHI if use rates exceed 2.75 oz/A (16).
Use in IPM: Because most of Actara's surface residue is quickly absorbed into the plant, negative impact on natural enemies is minimized (25).
Efficacy Issues: Is locally systemic with long residual inside the plant making it particularly effective on piercing/sucking insects (25).

MITICIDE PROFILES

Avermectin

(a natural fermentation product of *Streptomyces avermitilis*)

Formulations: Agri-Mek 0.15 EC. Restricted Use Pesticide.
Pests controlled: White apple leafhopper, spotted tentiform leafminer, European red mite (1).
% Crop acreage treated (NASS): 13% in 2001, 9% in 1999, 19% in 1997 (7).
Type of application: Ground applied only (16).
MI average rate per application (NASS): 0.01 lbs ai/A in 2001, 0.01 lbs ai/A in 1999 (7).
Number of applications (NASS): 1 time per season in 2001, 1.1 times per season in 1999 (7).
Timing: Petal fall: White apple leafhopper, spotted tentiform leafminer, European red mite **First cover:** European red mite, white apple leafhopper, spotted tentiform leafminer (1).
REI: 12 hours (16).
PHI: 28 days (16).
Efficacy issues: When mixed with horticultural spray oil, the fruit of several varieties of apples may be injured. See label for specifics (16).
Agri- Mek is locally systemic and, when applied before leaf tissue is mature and hard, has long residual inside the foliage (1).

Bifenazate

(cabazate)

Formulations: Acaramite 50W.
Pests controlled: European red mite, two-spotted spider mite (1).
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).

Number of applications: Not listed in the NASS data (7).
Timing: Apply as soon as mites appear (16).
REI: 12 hrs (16).
PHI: 7 days (16).
Use in IPM: Contact miticide primarily active against motile stages of European red mite and two spotted spider mite, but also nymphal stages that hatch after application (1).
Efficacy Issues: For best performance, maintain spray tank water at or near pH 7.0 (1).

Clofentezine
(tetrazine)

Formulations: Apollo SC.
Pests controlled: European red mite (1).
% Crop acreage treated (NASS): 8% in 2001, 21% in 1999, 6% in 1997, and 34% in 1995 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.12 lbs ai/A in 2001, 0.10 ai/A in 1999 (7).
Number of applications (NASS): 1 time per season in 2001, 1.3 times per season in 1999 (7).
Timing: Tight cluster or later - up to the 45 day PHI, but can be used only once per year (1).
REI: 12 hours (16).
PHI: 45 days (16).
Use in IPM: Apollo is an active mite ovicide, providing control ranging 10 weeks to full season depending on mite pressure, vegetative growth and predator population. It is not toxic to predator mites (1).

Dicofol
(chlorinated hydrocarbon)

Formulations: Kelthane 35 WP, Kelthane 50WP.
Pests controlled: Mites (1).
% Crop treated: Not recorded in the NASS Ag Chemical Usage for 2001 or 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): Not recorded in the NASS Ag Chemical Usage for 2001 or 1999 (7).
Number of applications: Not recorded in the NASS Ag Chemical Usage for 2001 or 1999 (7).
Timing: Third cover (1).
REI: 12 hours (16).
PHI: 7 days (16).
Use in IPM: Moderately toxic to mite predators. To avoid resistance, use only 1 or 2 times a season, and

only once against the same generation of mites (1).
Efficacy issues: Kelthane is primarily active against the motile stages of European red mite and two-spotted spider mite, but is also active against the nymphal stages that hatch after application. Temperature does not affect its activity (16).

Etoxazole

(IGR - diphenyloxazoline)

Formulations: Zeal 72 WG.
Pests controlled: European red mite, two-spotted spider mite.
% Crop Acreage treated: Not listed in the NASS data (7).
Type of application: Ground (16).
MI average rate per application: Not listed in the NASS data (7).
Number of applications: Not listed in the NASS data (7).
Timing: Apply when economic thresholds are reached; best control is achieved when mite populations are low (16).
REI: 12 hrs (16).
PHI: 28 days (16).
Use in IPM: Good resistance management option because of unique mode of action. Eight weeks to full season control depending on pest pressure (1).
Efficacy Issues: Exhibits pronounced translaminar movement in plant leaves, enhancing activity when the pest is located on the undersides of the leaves (1).

Formetanate

(carbamate)
See Insecticides.

Fenbutatin-oxide

(organic tin)

Formulations: Vendex 50 WP. Restricted Use Pesticide.
Pests controlled: Mites (1).
% Crop acreage treated: Not listed in NASS Ag Chemical Usage for 2001 or 1999 (7).
Type of application: Ground (16).
MI average rate per application: Not listed in NASS Ag Chemical Usage for 2001 or 1999 (7). Label rate is 1-2 lbs of product per acre (16).

Number of applications: Not listed in NASS Ag Chemical Usage for 2001 or 1999 (7). Label states no more than 2 applications per year (16).
Timing: When mites first appear (16).
REI: 48 hours (16).
PHI: 14 days (16).
Use in IPM: It is of low toxicity to predaceous mites and can be utilized to adjust predator-prey ratios (1).
Efficacy issues: Control is temperature dependent and is more effective in warm weather (1).

Hexythiazox (carboxamide)

Formulations: Savey 50 WP, 50 WF.
Pests controlled: European red mite, two-spotted spider mite.
% Crop acreage treated (NASS): 7 % in 2001, 3% in 1999 (7).
Type of application: Ground (16).
MI average rate per application (NASS): 0.09 lbs ai/A in 2001, 0.09 lbs ai/A in 1999 (7).
Number of applications (NASS): 1.1 applications per season in 2001, 1.1 application per season in 1999 (7).
Timing: It can be applied at pink stage or later in the season up to a 28 day PHI, but only one application per year is allowed (1).
REI: 12 hrs (16).
PHI: 28 days (16).
Use in IPM: Savey is an active mite ovicide and larvacide, providing control ranging 10 weeks to full season depending on mite pressure, the extent of vegetative growth and mite predator population. It is not toxic to predator mites (1).
Efficacy issues: Control is achieved when eggs come into direct contact with the spray or contact with treated plant surfaces. Can only be used once per year (1).

Oxamyl
(carbamate)
See Insecticides

Petroleum distillates
See insecticides

Pyridaben
(pyridazinone)

Formulations: Pyramite 60 WP.
Pests controlled: European red mite, two-spotted spider mite, apple rust mite, and leafhoppers.
% Crop acreage treated: 38% in 2001, 32 % in 1999 (7).
Type of application: Ground (16).
MI average rate per application: 0.15 lbs ai/A in 2001, 0.16 lbs ai/A in 1999.
Number of applications: 1.1 applications per season in 2001, 1.0 applications per season in 1999 (7).
Timing: Applications may be made from pink through petal-fall to control eggs and motile mites (16).
REI: 12 hrs (16).
PHI: 25 days (16).
Use in IPM: Effective against a broad spectrum of mites (1).
Efficacy issues: It is a contact miticide and requires good coverage to ensure pest will contact the product (1).

Diseases

Apple Scab
Venturia inaequalis

Apple scab lesions on fruit.

Symptoms: The fungus causing apple scab infects leaves, petioles, blossoms and fruit. Velvety brown to olive colored lesions usually develop first on the underside of leaves on fruit spurs. The lesions turn black with age. Initially the margins of the lesions are feathery and indefinite, but later they are distinct. Severe infection can cause extensive defoliation. If defoliation occurs two or three years in a row, the trees become more susceptible to winter low-temperature damage and bloom in following years may be reduced. Scab infections on the fruit initially resemble the leaf infections but become brown and corky with age, resulting in uneven growth and cracking of the skin and flesh. If fruit infection occurs in late

summer or early fall, rough, black, circular lesions may develop on the fruit in storage. These lesions are usually small, varying in size from specks to ¼ inch in diameter and are known as "pinpoint scab" (5).

Method of Transmission: The apple scab fungus overwinters in infected leaves on the orchard floor, and sometimes in apple buds. When the leaves become wet in the spring, ascospores are ejected and infect the emerging apple tissues. Primary scab lesions result. The primary lesions produce conidia (secondary or summer spores) that serve as sources of secondary infection to perpetuate the disease throughout the summer. The conidia are spread by wind and splashing rain (5, 14).

Conditions Favoring Disease: Spore dispersal is favored by rain and high humidity. Air temperature and length of the wetting period determine the severity of infection (14).

Management Practices: The key to effective scab control is to prevent fungus establishment during the springtime primary scab infection period. Fungicides are the primary control measure (5).
Cultural Controls: Innoculum in leaves on the orchard floor can be reduced but not eliminated by good sanitation practices in the orchard such as mowing the leaves prior to bud break and/or by applying 5% urea just prior to leaf fall (14).
Resistant Cultivars: Apple breeding programs at major U.S. universities have released more than 25 scab-resistant cultivars. The cultivars vary in their susceptibility to other early-season diseases; all are susceptible to summer diseases (5).
Chemical Controls: Apple scab is primarily controlled with fungicide sprays. A variety of fungicides are available; how and when they should be used depends on their mode of action (1).
Protectant fungicides prevent the spores from germinating or penetrating leaf tissue. To be effective, they must be applied to the surface of susceptible tissue before infection is predicted (using the Mills system). These chemicals are applied routinely 7 to 10 days apart, or according to anticipated rainfall (infection period).
Post-infection fungicides penetrate apple leaves, blossoms, and green fruit to inhibit lesion development from inside the tissue. The extent of after-infection fungicide activity is limited to a few hours or days after the onset of infection, and it often varies with the temperatures that prevail for 24 to 48 hours after spray application. Other post-infection fungicides can inhibit the fungus even later into the incubation period (pre-symptom control activity). The development of chlorotic scab lesions in leaves, or yellow leaves with green circular areas, indicates that the limits of pre-symptom control activity have been reached. Rarely can post-infection fungicides eradicate lesions after conidia sporulation has occurred. Eradication of lesions, referred to as post-symptom control activity results in lesions that appear to be "burnt out" (5).

Resistance problems are associated with the use of many fungicides, therefore anti-resistance strategies should be a part of scab control programs.

Products used for chemical control include Captan, Captec, Dithane, Manzate, Penncozeb, Polyram, Nova, Procure, Rubigan, Flint, Sovran, Syllit, Vangard, Topsin M, Ziram (1).

Fire Blight

Erwinia amylovora

Fire blight has caused significant losses to the apple industry in recent years. The bacterial disease will continue to threaten the industry because of increased planting of commercially valuable but highly susceptible cultivars and rootstocks, and the development of streptomycin resistant strains of the fire blight bacterium (5).

Symptoms: This pathogen kills the fruit-bearing spurs and branches and often, entire trees. It is distinguished by the presence of milky to reddish brown droplets of sticky liquid that ooze from the surface of infected tissues and fruit. Infected blossoms become water-soaked and darker green as the bacteria invade new tissues. Within a few days fruiting spurs collapse and turn brown. Infected shoots turn brown to black and bend into a shepherd's crook near the tip. Bark on infected branches is darker than normal and when peeled away, reveals reddish streaks when first invaded; later the tissues are brown. Eventually the margins of the branch cankers become sunken and sometimes cracked. Infected fruit develop a brown or black decay and, during wet, humid weather, may exude creamy drops of bacterial ooze. A number of apple rootstocks are susceptible, and infection by the fireblight bacterium can result in death of some or all the roots and crown (5).

Method of Transmission: The pathogen overwinters near the margins of cankers. Bacterial ooze begins to appear on the surface of cankers at or just before bloom in the spring. Splashing rain, honeybees and, occasionally, flies visit the bacterial ooze and then the blossoms, initiating primary infection. Honeybees rapidly spread the bacteria from flower to flower. Inoculum for secondary infection originates from droplets of ooze produced on infected flowers, fruit and shoots (5).

Conditions Favoring Disease: Infection is favored by temperatures between 65 and 86ºF, accompanied by rain or high humidity. Infection normally occurs through natural openings in the plant, however, storms containing wind-driven rain or hail are important in spreading bacteria during the summer, leading to sudden and severe outbreaks of fire blight (5).

Management Practices: *Sanitation:* In summer, orchards should be inspected weekly beginning about 10 days after petal fall to remove cankers and infected spurs and terminals. Dormant pruning to remove

overwintering cankers is also very important. Pruning must be done at least 12-18 inches below any visible sign of infection.
Insect control: Controlling sucking insects will prevent wounds where bacteria can enter. *Resistant cultivars:* Apple cultivars vary in resistance to fire blight, but none are immune. Rootstocks such as M.26 and M.9 are very susceptible.
Cultural Practices: Lesion development and damage from fire blight is more severe when tree growth continues late into the season. Plant orchards on well drained soil, apply nitrogen fertilizer early and, to stop growth, avoid cultivating orchards later than midsummer (5).
Chemical control: Copper sprays at green tip may reduce inoculum on bark from overwintering cankers. Antibiotics have been highly effective against the blossom phase of fire blight, preventing infection from getting started in an orchard. Predictive models, particularly MARYBLYT, help growers identify potential infection periods so treatments are not wasted. In recent years, resistance to streptomycin has appeared in strains of *E. amylovora* in some Michigan orchards. Oxytetracycline (Mycoshield) is a useful replacement for streptomycin (Agrimycin) in areas where streptomycin resistance has been a problem, or may be used in combination with streptomycin as part of an anti-resistance management program (1, 5, 18).

Powdery Mildew
Podospaera leucotricha


Powdery mildew is an important fungal disease in apple orchards. Losses result from death of vegetative shoots, death of lower buds, and loss of fruit quality.

Symptoms: Mildew occurs in the orchard on leaves, flowers, shoots and fruit. It appears as whitish, felt-like patches of fungal mycelium and spores on the undersides and along the margins of leaves. The lesions spread rapidly and may engulf the entire leaf. Infected leaves are narrower than normal, folded longitudinally, and become stiff and brittle with age. The petals of infected flowers are pale yellow or light green, distorted, and stunted. Infected flower buds are more susceptible to spring frost and exhibit reduced fruit-set. Infected terminals produce stunted leaves and shoots. Infected fruit are small and show a net-like russeting (5).

Method of Transmission: The mildew fungus overwinters as mycelium in buds infected the previous summer. When buds open in the spring, the fungus begins to produce spores (conidia), which are distributed by the wind and cause primary infections on young leaves, blossoms and fruit. Initial infections provide inoculum for secondary infection cycles on leaves, shoots and fruit (18).

Conditions Favoring Disease: Unlike apple scab, powdery mildew spores germinate readily in the absence of free moisture at high humidity with temperatures between 60 and 80ºF. Temperatures between 40 and 50ºF slow spore germination and mycelial development. Both are significantly reduced at temperatures above 90ºF (5).

Management Practices:
Chemical control: Application of a mildewcide beginning at tight cluster and continued until terminal growth stops can control powdery mildew. Early sprays (tight cluster to petal fall) are essential to success in controlling powdery mildew (5). Products recommended for use in Michigan include Bayleton, Nova, Rubigan, Procure, Flint, Sovran and sulfur (1).

Sooty blotch and fly speck

Peltaster fructicola & Zygophiala jamaicensis

Severe sooty blotch on a Golden Delicious apple.

Fly speck on apple fruit.

These two summer diseases, which arise from similar environmental conditions, can cause moderate to severe damage on the fruit, lowering fruit quality and market value (18).

Symptoms: When sooty blotch and fly speck occur together on fruit, the colonies are mutually exclusive. Sooty blotch appears as superficial sooty or cloudy blotches on the surface of fruit. Blotches are brown to olive green and indefinite in outline. The fungi that cause sooty blotch produce clusters of colonies that range in appearance from sooty and smudge-like to much darker colonies with many small, circular pycnidia scattered within them (5).

Flyspeck appears on fruit as sharply defined, black, shiny dots in groups of a few to nearly 100. These dots or specks are sexual fruiting structures called pseudotheciea. They are much larger than the pycnidia associated with the most common types of sooty blotch colonies (5).

Method of Transmission: Both pathogens overwinter on twigs of many woody plants. Spread of the sooty blotch fungus from overwintering hosts is by waterborne conidia or mycelial fragments. Primary infection by the flyspeck fungus is by airborne ascospores, which are discharged during rainy periods. Secondary infections occur by conidia, which are airborne or waterborne. Fruit infection can occur anytime after petal fall but is most prevalent in mid to late summer (5).

Conditions Favoring Disease: In northern states, disease outbreaks are favored by extended periods of above normal summer temperatures combined with frequent rainfall (5).

Management Practices: Control is achieved through sanitation, cultural practices and the use of fungicides.
Sanitiation: Removing reservoir hosts, particularly brambles, from the orchard and surrounding hedgerows helps to reduce inoculum, but in wet years this, by itself, may not be adequate for disease control (5, 18).
Cultural practices: Dormant and summer pruning to open the tree canopy, fruit thinning and other practices to promote air movement and fruit drying after rain or dew will help to prevent disease. Both diseases are very difficult to control in orchards or in areas of orchards with restricted air movement (5).
Chemical control: Fungicide treatments are initiated 1 to 2 weeks after petal fall, then repeated on a 10 to 14 day schedule until 2 to 3 weeks before harvest. Alternatively, timing of the first application may be based on the number of hours of leaf wetting that have accumulated since 10 days after petal fall. The first spray for sooty blotch is probably not needed until 300 hours of leaf wetness have been accumulated (18). Cover sprays starting at third cover include Captan (captan), Ziram (ziram), Flint, Sovran or Topsin M (thiophanate-methyl) plus Captan or Ziram (1).

FUNGICIDE PROFILES

Captan
(dicarboximide: phthalimide)

Formulations: Captan 50 WP, Captan 80 WP, Captan 4 FL.
Pests controlled: Apple scab, sooty blotch and flyspeck.
% Crop acreage treated: 91% in 2001, 90% in 1999 (7).
Type of application: Ground (16).
Application rates: 1.7 lbs ai/A in 2001, 1.9 lbs ai/A in 1999 (7).
Number of applications: 5.3 times per season in 2001, 5.3 times per season in 1999 (7).
Timing: Apply at 5- to 7-day intervals as needed to maintain control in pre-bloom, bloom, petal fall and first cover sprays for primary scab. Apply at 10-14 day intervals in second and later cover sprays for secondary scab and sootyblotch/flyspeck (16).

REI: 4 days (16).
PHI: 0 days (16).
Use in IPM: Provides 5-6 days of protectant activity and one day of after-infection activity (1).

Copper hydroxide
(inorganic)

Formulations: Champ Formula 2 and Champ Formula II, Kocide 101.
Pests controlled: Apple scab and fireblight.
% Crop acreage treated: 22% in 2001, 23% in 1999 (7).
Type of application: Ground (16).
Application rates: 1.7 lbs ai/A in 2001, 1.1 lbs ai/A in 1999 (7).
Number of applications: 1.2 times per season in 2001, 1.5 times per season in 1999 (7).
Timing: Use as a full cover spray between silver tip and green tip (16).
REI: 24 hours (16).
Use in IPM: 2-3 days of protectant activity with little or no back action. Can be phytotoxic to foliage and fruit and should not be applied after the 1/4" green stage (1).

Copper Sulfate
(inorganic)

Formulations: Basicop.
Pests controlled: Apple scab and fireblight (16).
% Crop acreage treated: 10% in 2001, 4% in 1999 (7).
Type of application: Ground (16).
Application rates: 1.64 lbs ai/A in 2001, 1.26 lbs ai/A in 1999 (7).
Number of applications: 1.3 times per season in 2001, 1.5 times per season in 1999 (7).
Timing: *Fireblight*: apply at 5 day intervals from 10% bloom to the end of bloom; *Apple scab*: with the addition of hydrated lime, apply at delayed dormant (16).
REI: 24 hours (16).
Use in IPM: 2-3 days of protectant activity, little to no back action, can be phytotoxic to foliage and fruit and should not be applied after the 1/4" green stage (1).

Dodine
(guanidine organic compound)

Formulations: Syllit 65W.
Pests controlled: Apple scab.
% Crop acreage treated: Less than 1% in 2001, not listed in NASS data in 1999 (7).
Type of application: Ground (16).
Application rates: 1.5 lbs ai/A in 2001 (7).
Number of applications: 1.5 times per season in 2001(7).
Timing: 24-36 hours of after-infection activity will inactivate sporulating lesions – 2 applications at high rates one week apart are needed (1).
REI: 48 hours (16).
PHI: 7 days (16).
Efficacy issues: Scab resistance is a significant problem in Michigan (1).

Fenarimol
(pyrimidine)

Formulations: Rubigan 1EC.
Pests controlled: Apple scab and powdery mildew.
% Crop acreage treated: 14% in 2001, 30% in 1999 (7).
Type of application: Ground (16).
Application rates: 0.05 lbs ai/A in 2001, 0.05 lbs ai/A in 1999 (7).
Number of applications: 2.4 times per season in 2001, 2.6 times per season in 1999 (7).
Timing: *Apple scab*: begin at green tip or when environmental conditions favor scab development and post infection. *Powdery mildew*: tight cluster through cover sprays (16).
REI: 12 hours (16).
PHI: 30 days (16).
Use in IPM: For apple scab it has 2-3 days of protection activity and 4 days of after-infection activity. Back-to-back sprays give increased after-infection control and are locally systemic in foliage (1).

Fosetyl-Al
(organophosphate)

Formulations: Aliette 80 WDG and Aliette.
Pests controlled: Phytophthora collar rot.
% Crop acreage treated: Not included in the 2001 or 1999 NASS data (7).
Type of application: Ground (16).
Application rates: Not included in the 2001 or 1999 NASS data (7).
Number of applications: Not included in the 2001 or 1999 NASS data (7).
Timing: Begin applications at the start of the growing season and repeat every 60 days with maximum

of 4 applications per year (1).
REI: 12 hours (16).
PHI: 14 days (16).
Use in IPM: Chemical control is a stop gap measure and not a substitute for good cultural practices to control Phytophthora collar rot (1).

Mancozeb
(dithiocarbamate)

Formulations: Dithane M-45, Manzate 200 DF, Penncozeb 80 WP, Penncozeb 75DF.
Pests controlled: Apple scab.
% Crop acreage treated: 66% in 2001, 49% in 1999, 46% in 1997, 27% in 1995 and 18% in 1993 (7).
Type of application: Ground (16).
Application rates: 2.41 lbs ai/A in 2001, 2.49 lbs ai/A in 1999 (7).
Number of applications: 3.6 times per season in 2001, 4.4 times per season in 1999 (7).
Timing: As needed up to 77 days before harvest (16).
REI: 24 hours (16).
PHI: 77 days (16).
Use in IPM: Has 5-6 days of protection when used at full rate, 18-24 hours of after-infection activity and has very good retention and redistribution (1).

The baby food industry allows EBDCs for early season use only (11).

Metiram
(dithiocarbamate)

Formulations: Polyram 80 DF.
Pests controlled: Apple scab.
% Crop acreage treated: 39% in 2001, 27% in 1999 (7).
Type of application: Ground (16).
Application rates: 2.43 lbs ai/A in 2001, 2.79 lbs ai/A in 1999 (7).
Number of applications: 3.4 times per season in 2001, 3.5 times per season in 1999 (7).
Timing: As needed through the season up to 77 days before harvest (16).
REI: 24 hours (16).
PHI: 77 days (16).
Use in IPM: Has 5-6 days of protection when used at full rate, 18-24 hours of after-infection activity and has very good retention and redistribution (1).

The baby food industry allows EBDCs for early season use only (11).

Myclobutanil
(triazole)

Formulations: Nova 40W
Pests controlled: Apple scab and powdery mildew.
% Crop acreage treated: 40% in 2001, 57% in 1999 (7).
Type of application: Ground (16).
Application rates: 0.09 lbs ai/A in 2001, 0.10 lbs ai/A in 1999 (7).
Number of applications: 2.9 times per season in 2001, 3.1 times per season in 1999 (7).
Timing: *Powdery Mildew*: tight cluster to second cover or beyond. *Apple scab*: start at green tip and apply on a 7-10 day schedule (16).
REI: 24 hours (16).
PHI: 14 days (16).
Ise in IPM: Normally tank mixed with a protective fungicide. Has 3-4 days of protection activity for apple scab and 96 hours of after-infection activity. Back-to-back sprays give increased after-infection control and are locally systemic in foliage. Has good to excellent rating for apple scab control, excellent rating for powdery mildew (1).

The baby food industry allows myclobutanil use through petal fall (11).

Streptomycin
(antibiotic)

Formulations: Agrimycin 17 Ag.
Pests controlled: Fire blight.
% Crop acreage treated: 42% in 2001, 45% in 1999 (7).
Type of application: Ground (16).
Application rates: 0.22 lb ai/A in 2001, 0.16lb/A in 1999 (7).
Number of applications: 1.9 times per season in 2001, 1.4 times per season in 1999 (7).
Timing: Best timing is achieved using the MARYBLYT model. If that is not available, an “Orchard Risk Chart” should be used to compare daily temperature and rainfall as risk factors for fireblight (1).
REI: 12 hours (16).
PHI: 50 days (16).
Use in IPM: Streptomycin is more effective against fire blight than Mycoshield where bacteria are not resistant. Streptomycin-resistant strains of the fire blight bacterium (*Erwinia amylovora*) have been detected in several orchards in VanBuren County, Kent County and Newaygo County (1).

Sulfur
(inorganic)

Formulations: Microthiol Special, Wettable Sulfur 90 WP.
Pests controlled: Apple scab, powdery mildew.
% Crop acreage treated: 40% in 2001, 41% in 1999 (7).
Type of application: Ground (16).
Application rates: 3.26 lbs ai/A in 2001, 3.63 lbs ai/A in 1999 (7).
Number of applications: 3.7 times per season in 2001, 4.8 times per season in 1999 (7).
Timing: Pre-bloom and at petal fall (16).
REI: 12 to 24 hours (1).
PHI: 0 days (1).
Use in IPM: For apple scab it has 2-3 days of protectant activity, no after-infection activity and has poor retention and fair redistribution. High rates are required for scab control, lower rates are used to suppress powdery mildew (1).

Thiophanate-methyl
(benzimidazole)

Formulations: Topsin M 70 WP.
Pests controlled: Powdery mildew, sooty blotch and flyspeck.
% Crop acreage treated: 3% in 1999. Not listed in NASS data for 2001 (7).
Type of application: Ground (16).
Application rates: 0.56 lbs ai/A in 1999. Not listed in NASS data for 2001 (7).
Number of applications: 1.3 times per season in 1999. Not listed in NASS data for 2001 (7).
Timing: Apply 5 to 10 day intervals from green tip through petal fall. Continue at 7-14 day intervals for cover sprays. For resistance management, always tank mix Topsin M with a fungicide of a different class (16).
REI: 12 hours (16).
PHI: 0 days (1).
Efficacy issues: There are scab resistance problems and it is not recommended for control of scab. It has good control for powdery mildew and sooty blotch and flyspeck (1).

The baby food industry allows its use through bloom only (11).

Triadimefon
(triazole)

Formulations: Bayleton 50 DF.
Pests controlled: Powdery mildew and cedar-apple rust.
% Crop acreage treated: 22% in 2001, 19% in 1999 (7).
Type of application: Ground (16).
Application rates: 0.06 lbs ai/A in both 2001 and 1999 (7).
Number of applications: 2.2 times per season in 2001, 1.9 times per season in 1999 (7).
Timing: Make first application at green tip stage and continue at 7-14 day intervals until terminal growth ceases (16).
REI: 12 hours (16).
PHI: 45 days (16).
Use in IPM: Alternating or tank mixing Bayleton with a non-SI fungicide is recommended for resistance management.

Ziram
(carbamate)

Formulations: Ziram 76 DF.
Pests controlled: Apple scab and sooty blotch and flyspeck.
% Crop acreage treated: 45% in 2001, 46% in 1999, 33% in 1997 (7).
Type of application: Ground (16).
Application rates: 2.4 lbs ai/A in 2001, 2.6 lbs ai/A in 1999 (7).
Number of applications: 2.6 times per season in 2001, 2.4 times per season in 1999 (7).
Timing: Pre-bloom and cover sprays as needed (16).
REI: 48 hours (16).
PHI: 14 days (16).
The baby food industry allows Ziram to be used up to a 45 day PHI (11).
Use in IPM: It is a weak protector against apple scab with 3-5 days of protection activity and no after-infection activity. It has a fair rating for scab, fair for sooty blotch and flyspeck (1).

Weed Management

Ground cover management affects both fruit tree vigor and yield. A vegetation-free area in the tree row, usually from the trunk to the dripline, results in larger trees, more fruit set and more total yield because the trees are free from root competition. Weeds under the trees not only compete directly with the trees for moisture and nutrients, they also harbor or host rodents, insects, nematodes and diseases and can

compete for pollinating bees in spring. Sod or a cover crop is usually established in the alleyways to support vehicle travel and control erosion.

A new orchard site must be repeatedly tilled and/or treated with herbicides in order to destroy perennial weeds such as quackgrass, nutsedge and Canada thistle. Optimum weed-free growing conditions must be provided for the first few seasons to produce a healthy tree with a strong trunk and scaffold branches. Annual weeds must also be controlled while trees are actively growing.

Generally, fruit trees gain herbicide tolerance with age. However, trees growing on sandy soils that are low in organic matter are more susceptible to soil-applied herbicides than trees growing on heavier, loam soils.

It is important to follow a resistance management program when using herbicides. Know what weeds you are trying to control, avoid continuous use of the same herbicide and combine two soil-active herbicides for a wider spectrum of weed control (1).

HERBICIDE PROFILES

2,4-D
(phenoxy acetic acid)

Formulations: Weedar 64, Hi Dep.
Pests controlled: Perennial broadleaves such as dandelions, field bindweed, and common milkweed (1).
% Crop acreage treated: 14% in 2001, 19% in 1999, 23% in 1997 (7).
Type of application: Applied to sodded alleyways. Use low pressure to avoid drift to trees (1).
Application rates: 0.53 lbs ai/A in 2001, 0.61 lbs ai/A in 1999 (7).
Number of applications: 1.3 times per season in 2001, 1.0 times per season in 1999 (7).
Timing: Postemergence, and applications after harvest and before frost are preferred. Do not apply during bloom (1).
REI: 48 hours (16).
PHI: 40 days (16).
Use in IPM: Trees must be at least one year old and in vigorous condition before product is used (16).

Diuron
(substituted urea)

Formulations: Karmex 80 DF.

Pests controlled: Annual grasses and broad-leaved weeds (1).
% Crop acreage treated: 14% in 2001, 21% in 1999 (7).
Type of application: If ground applied prior to emergence of weeds, it will provide acceptable weed control for the growing season. It can be used with paraquat or glyphosate or tank-mixed with other soil-active herbicides for improved control of a wider range of weed species (1).
Application rates: 0.53 lbs ai/A in 2001, 0.33 lbs ai/A in 1999 (7).
Number of applications: 1.3 times per season in 2001, 2.1 times per season in 1999 (7).
Timing: Apply in spring when weeds emerge (1).
REI: 12 hours (16).

Fluazifop-P
(phenoxy)

Formulations: Fusilade DX.
Pests controlled: Grasses (1).
% Crop acreage treated: Not included in the NASS data for 2001 or 1999 (7).
Type of application: Ground (16).
Application Rates: Rates vary by grass species. See label (16).
Timing: Can only be used on non-bearing apple trees (16). Apply to actively growing grasses before they exceed growth stage specified on product label. Avoid spray contact with fruit tree foliage (1).
REI: 12 hrs (1).

Glufosinate
(organophosphate)

Formulations: Rely.
Pests controlled: A broad spectrum of emerged annual and perennial grasses and broadleaf weeds (1).
% Crop acreage treated: Not included in the NASS data for 2001 or 1999 (7).
Type of application: Directed spray (16).
Application Rates: See label. Rates vary by type of application (16).
Timing: Apply to actively growing weeds. Avoid contact with green or uncallused bark on young trees. Avoid contact with foliage (1).
REI: 12 hrs (16).
PHI: 14 days (16).

Glyphosate

(organophosphate)

Formulations: Roundup Ultra.
Pests controlled: Annual and perennial weeds (1).
% Crop acreage treated: 29% in 2001, 57% in 1999, 44% in 1997 (7).
Type of application: directed-spray ground application (16).
Application rates: 0.75 lbs ai/A in 2001, 0.42 lbs ai/A in 1999 (7).
Number of applications: 1.0 time per season in 2001, 2.0 times per season in 1999 (7).
Timing: postemergence (16).
REI: 4 hrs (16).
PHI: 1 day (16).
Use in IPM: Apply only near trees established for 2 years or more (1).

Norflurazon
(pyridazinone)

Formulations: Solicam.
Pests controlled: More effective on grasses than broadleaves and does not control established weeds (1).
% Crop acreage treated: Not included in the NASS data for 2001 or 1999.
Type of application: Directed spray to the soil (16).
Application Rates: 2.2 to 5.0 lbs product recommended per acre (1).
Timing: Apply before weeds emerge or combine with paraquat or glyphosate for control of existing vegetation. More effective when applied in the fall. Rain is necessary to move the chemical into the weed root zone for it to be effective (1).
REI: 12 hrs (16).
PHI: 60 days (16).
Use in IPM: Can be applied to newly planted apple trees after trees are established (1).

Oryzalin
(dinitroaniline)

Formulations: Surflan.
Pests controlled: A preemergence herbicide effective in controlling annual grasses and many annual broadleaved weeds. It has little effect on established weeds and grasses but may be combined with paraquat or glyphosate to kill established weeds and prevent regrowth (1).
% Crop acreage treated: Not listed in the NASS data for 2001 or 1999 (7).
Type of application: Ground (16).

Application Rates: 2 to 4 qts product recommended per acre (1).
Timing: Preemergence. One-half to one inch of rain or irrigation is needed to activate the herbicide (1).
REI: 24 hrs (16).
Use in IPM: Can be used safely on newly planted fruit trees after the soil has settled and no cracks are present (1).

Oxyfluorfen
(nitrophenyl ether)

Formulations: Goal.
Pests controlled: Pre- and postemergent control of a wide range of weeds (16).
% Crop acreage treated: Not listed in the NASS data for 2001 and 1999 (7).
Type of application: Directed spray to the base of trees (1).
Application Rates: 3-4 qts recommended per acre (1).
Timing: Preemergence or postemergence (16).
REI: 24 hrs (16).
Use in IPM: Can be applied to dormant, non-bearing or bearing tree fruit (1).

Paraquat
(bipyridylium)

Formulations: Gramoxone Max. RESTRICTED USE PESTICIDE.
Pests controlled: Annual and perennial weeds (1).
% Crop acreage treated: 16% in 2001, 28 % in 1999 (7).
Type of application: Ground-directed spray when weeds and grasses are succulent and new growth is 1 to 6 inches high (16).
Application rates: 0.38 lbs ai/A in 2001, 0.46 lbs ai/A in 1999 (7).
Number of applications: 1.2 times per season in 2001, 1.4 times per season in 1999 (7).
Timing: Postemergence (16).
REI: 12 hours (16).

Pronamide
(amide)

Formulations: Kerb.
Pests controlled: Most effective on grasses and a few broadleaved weeds (1).

% Crop acreage treated: Not included in the NASS data for 2001 or 1999 (7).
Type of application: Directed spray (16).
Application Rates: 2 to 4 lbs product per acre (1).
Timing: Apply in fall after fruit harvest but prior to leaf drop. Do not apply to trees planted less than 6 months (1).
REI: 24 hrs (16).

Sethoxydim
(cyclohexine oxime)

Formulations: Poast.
Pests controlled: Actively growing grasses (1).
% Crop acreage treated: Not included in the NASS data for 2001 or 1999 (7).
Type of application: Ground (16).
Application Rates: Year of planting: 1.5 - 2.5 pts product per acre (1). Established one year or more: 2-4 pts product per acre (1).
Timing: Apply to actively growing grasses (1).
REI: 12 hrs (16).
PHI: 14 days (16).

Simazine
(triazine)

Formulations: Princep 90 WG, Princep 4 L.
Pests controlled: Germinating annual weeds. When used in the spring in combination with paraquat or glyphosate, quackgrass is suppressed (1).
% Crop acreage treated: 10% in 2001, 21% in 1999, 32% in 1997 (7).
Type of application: Directed spray (16).
Application rates: 1.03 lb ai/A in 2001, 0.9 lb ai/A in 1999 (7).
Number of applications: 1 time per season in 2001, 1.0 time per season in 1999 (7).
Timing: Spring (1).
REI: 12 hours (16).

Terbacil
(uracil)

Formulations: Sinbar 80 WP.
Pests controlled: Controls annual weeds and suppresses the growth of some perennial weeds (1).
% Crop acreage treated: 10% in 2001, 6% in 1999, 10% in 1997 (7).
Type of application: Directed spray (16).
Application rates: 0.26 lbs ai/A in 2001, 0.35 lbs ai/A in 1999 (7).
Number of applications: 1.0 time per season in 2001, 1.1 times per season in 1999 (7).
Timing: April 15 to May 1 (1).
REI: 12 hours (16).
PHI: 60 days (16).
Use in IPM: Use only on apples that have been established for at least 3 years (1).

Nematodes

Nematodes can be a problem in new orchard sites, but they are more likely to be a problem in replanted sites. Poor growth of replanted apple trees is the most obvious symptom. Trees are stunted and root systems are small, discolored and have poorly developed feeder roots. Trees may die after the first or second growing season or survive but never reach full production potential. Symptoms caused by nematodes can be similar to those caused by other factors so soil and root testing for the presence of nematodes is advised. Plant parasitic nematodes can also hinder the development of beneficial fungi necessary for normal tree growth.

Research has shown that many fruit crops respond to nematicides. As a first step, however, it is important to purchase high quality nursery stock produced in nematode-free, fumigated or nematicide-treated soil. Populations of plant-parasitic nematodes can be reduced below fruit-crop injury levels through fallowing, use of cover crops and application of fumigant or non-fumigant nematicides. Soil fumigation or use of a non-fumigant nematicide prior to planting in old fruit sites is often essential for development of healthy and productive orchards.

Nematodes either live and feed in roots as endoparasites or they live in orchard soil and feed on the surface of roots as ectoparasites. Both types migrate through soil from root to root and can be moved from orchard to orchard on mechanical equipment, in root stocks or in irrigation water. Population densities of root-lesion, dagger and ring nematodes frequently exceed damage thresholds in Michigan orchards. Northern root-knot, stubby-root, needle and lance nematodes have also been know to cause problems (19).

Root-Lesion Nematode: All life cycle stages of this nematode overwinter in Michigan. Root-lesion nematodes cause more damage and build to higher densities in sandy soils than in heavier soils. *P. penetrans* is the most common root lesion-nematode found in Michigan.

Lance Nematode: Lance nematode is a relatively large nematode that is known to be a problem in a few orchards in Michigan. The only species know to exist in Michigan is *Hoplolaimus galeatus*.

Dagger Nematode: Several species of dagger nematodes are found in Michigan; the most common is *Xiphinema americanum*. The dagger nematode is a vector for tomato ringspot virus which causes brown ring union necrosis of apples and plums.

Ring Nematode: The ring nematode is frequently recovered from Michigan orchards. *Criconemella xenoplax* is the most common species. High population densities of this nematode can inhibit normal growth and development of roots.

Stubby-Root Nematode: The stubby-root nematodes *Trichodorus* spp. and *Paratrichodorus* spp. occur in high population densities in a number of Michigan orchards. Root feeding causes stimulation of secondary feeder roots which become short and stubby.

Root-Knot Nematode: Northern root-know nematodes (*Meloidogyne hapla*) form galls on the roots of fruit trees and other hosts. This nematode can be introduced into orchard sites in infested nursery stock.

Needle Nematode: The only species known to exist in Michigan orchards is *Longidorus elongatus*. It is found in a small number of Michigan orchards. It is known to be a vector of a number of important viruses but is not known to be of significance as a virus vector in Michigan orchards (19).

NEMATICIDE PROFILES

Preplant Application

1,3-D

(chlorinated hydrocarbon)

Formulations: Telone II. RESTRICTED USE PESTICIDE (16).
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.
Application Rate: Broadcast: 30 gal/A (1).
Types of Application: Shank injection (1).
Timing: Apply as a preplant treatment into well prepared soil at least 21 days prior to planting. Soil temperatures should be between 50 and 80ºF. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60ºF or if the soil is very wet (1).
PHI: None applicable.

REI: 5 days (16).
IPM Concerns: Do not apply within 100 feet of any well used for potable water (16).

1,3-D and Chloropicrin

(chlorinated hydrocarbon)

Formulations: Telone C-17. RESTRICTED USE PESTICIDE.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in NASS data.
Application Rate: Broadcast: 35 gal/A (1).
Types of Application: Shank injection (1).
Timing: Apply as a preplant treatment into well-prepared soil at least 21 days prior to planting. Soil temperatures should be between 50 and 80°F. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60°F or if the soil is very wet (1).
PHI: None applicable.
REI: 5 days (16).
IPM Concerns: Do not apply within 100 feet of any well used for potable water (16).

Formulations: Telone C-35. RESTRICTED USE PESTICIDE.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.
Application Rate: Broadcast: 39-50 gal/A (1).
Types of Application: Shank injection (1).
Timing: Apply as a preplant treatment into well-prepared soil at least 21 days prior to planting. Soil temperatures should be between 50 and 80°F. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60°F or if the soil is very wet (1).
PHI: None applicable.
REI: 5 days (16).
IPM Concerns: Do not apply within 100 feet of any well used for potable water (16).

Metham

(carbamate)

Formulations: Busan 1020 and Vapam.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.

Application Rate: Broadcast: 50 to 100 gal/A (1).
Types of Application: Inject 4 inches deep (1).
Timing: Apply as a preplant treatment into moist soil at least 21 days prior to planting. Soil temperatures should be between 40 and 70°F. Inject to a soil depth of 4 inches with blades spaced 5 inches apart. Follow immediately with a roller to smooth and compact surface. Light watering or a tarp after rolling helps prevent gas escape. Fumigant should be applied with equal parts water or in a 2 to 1, water to fumigant, ratio (1).
PHI: None applicable.
REI: 48 hours (16).
IPM Concerns: Toxic to fish (16).

Oxamyl
(carbamate)

Formulations: Vydate L. RESTRICTED USE PESTICIDE.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.
Application Rate: Broadcast: 3-4 gal/A (1).
Types of Application: Ground (1).
Timing: Apply in a minimum of 20 gallons of water per acre. Thoroughly incorporate product with a rotary tiller to a depth of 48 inches immediately after application (1).
PHI: Not applicable.
REI: 48 hours (16).

NEMATICIDE PROFILES
Post-Plant Treatment

Fenamiphos
(organophosphate)

Formulations: Nemacur 3.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.
Application Rate: Band: 1.67-2.5 gal/A (1).
Types of Application: Ground (banded) (1).
Timing: Post-plant application. Apply in not less than 10 gallons of water per acre and incorporate immediately either mechanically or with sufficient irrigation. Center the treated band over the tree row

with width of 4-6 ft. Do not apply more than 2.5 gallons per acre per site per year (1).
PHI: 72 hours (1).
REI: 48hrs (16).
IPM Concerns: Avoid contacting tree foliage with the spray mixture (1).

Oxamyl
(carbamate)

Formulations: Vydate L. RESTRICTED USE PESTICIDE.
Pests Controlled: Nematodes.
Acres of Crop Treated: Not listed in the NASS data.
Application Rate: Foliar spray: 2-4 pts/A (1).
Types of Application: Ground (1).
Timing: Mix in 100 gallons of water and apply as a dilute spray to foliage. Apply on a 2-3 week schedule for 4 applications (1).
PHI: For non-bearing orchards only. Do not apply to trees that will bear fruit within 12 months of the last application (1).
REI: 48 hours (16).

Post Harvest Disease and Disorders

Apple storage scald is a troublesome physiological disorder affecting susceptible apple varieties during storage and marketing.

Symptoms: Storage scald initially appears as a browning of the skin and makes the apple unacceptable for fresh market. Susceptible varieties include McIntosh, Cortland, Mutsu, Delicious, Greening, Stayman Winesap, Turley Winesap and Rome Beauty (Red Rome). Scald occasionally develops on Jonathan, Idared and Golden Delicious.

Management Practices: Fruit storage in atmospheres having 1.5% oxygen or less reduces the incidence and severity of superficial scald, but may not offer complete control.

Using the antioxidant diphenylamine (DPA), can prevent scald development. Rates of 1,000 or 2,000 ppm are used, depending on the temperature of the fruit and the degree of susceptibility to scald. Dip or drench the fruit shortly after harvest. A delay of two weeks in storage considerably reduces scald control with chemicals. There are some restrictions on the export of fruit treated with scald inhibitors, so the destination of the stored fruit should be considered before choosing chemical treatment. The addition of a fungicide in the drench water may be necessary to reduce the incidence of decay.

Internal Breakdown and Bitter Pit of Apples

Internal breakdown is characterized by browning of the flesh followed by excessive softening and finally skin discoloration. It is retarded by good fruit handling and storage practices and by post-harvest treatment with calcium chloride.

Bitter pit appears as dry, brown spots of tissue before and after harvest. Its development can be retarded during storage by treatment with calcium chloride.

Dip or drench harvested apples in a 2.5% solution of calcium chloride containing 20 pounds of actual calcium chloride per 100 gallons of water. The calcium chloride must meet Food Chemical Codex specifications. Treated fruit should be stored immediately or put under cover to avoid loss of the material which must remain on the fruit during the storage period to be effective.

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