

Michigan Apple
Pest Management Strategic Plan

Completed July 2008

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Committee members met four times between February and April 2008 to develop the first draft document.

Project Initiated by Industry Committee:	June 28, 2000
Workshop for Planning / Outline Development:	February 8, 2008
Workshop for document development:	March 17, 2008
Workshop for document development:	March 28, 2008
Workshop for document development:	April 16, 2008
Industry Draft Review:	July 2008

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Section I. Pest Management Priorities

Introduction

The Michigan apple industry has recognized the need to be proactive in responding to changes in the availability and efficacy of insecticides, as well as changing societal and environmental concerns. Growers, in partnership with land-grant universities and the USDA, have developed a strategic plan that identifies regulatory, research and educational priorities that reflect their needs, and documents the apple industries progress toward greater reliance on new chemistries and other selective tactics for pest control.

Many factors acting together, however, have accelerated the need to develop alternative control tactics. Pest resistance to insecticides appears to be on the increase in some Michigan fruit growing areas. Broad-spectrum insecticides are highly toxic to natural enemies of most pests, and their use is a major factor limiting the potential of biological control in fruit orchards. New regulations governing pesticides, particularly the Food Quality Protection Act (FQPA), and the public's interest in reducing the use of insecticides have created uncertainty as to the future availability of many pesticides that are based on conventional chemistries. The most recent MSU Pesticides at Risk database indicated that at least 5 of the 20 most at risk pesticide-crop uses are OP's or CB's on apple.

Priorities for Apple Pest Management

Research

Insects

1. Develop and implement economic and effective OP-alternative and Reduced Risk strategies for in-season control of internal fruit feeding pests under Michigan climactic conditions.
 - a) Evaluate insecticides (including insect growth regulators) not currently labeled for apple, particularly those with novel modes of action.
 - b) Understand how new insecticides work (lethal and sublethal effects), and how this impacts timing.
 - c.) Develop and test economical mating disruption technologies (especially machine applied and multi-species formulations).
 - d.) Develop and integrate new control tactics in a biological and ecologically sound manner.
 - e.) Develop and integrate biopesticide and biological control agents into apple IPM.
 - f.) Improve monitoring and application timing protocols (phenology models).
2. Develop and implement measures of orchard functional ecology.
 - a) Impacts of management practices (orchard health/sustainability & natural enemy abundance and diversity).
 - b) Secure USEPA Re-registration of key pesticide tools.
 - c) Improved knowledge of adjacent landscape (areawide) effects on IPM.
3. Develop monitoring and control strategies for secondary pests previously controlled by OP's (including leafrollers, pest mites, borers, Japanese beetle, wooly apple aphid, scale, true bugs).
4. Continue evaluation of breeding potential for genetic traits in apple rootstock and cultivar that could confer resistance to insect pests.

5. Identify resistance genes that could be introduced to desirable cultivars.
6. Implement new cultural practices, including strategies of orchard floor management that enhance insect control.

Diseases

1. Develop and implement protocols for incorporating streptomycin alternatives for in-season control of fire blight.
 - a. Evaluate antibiotics not currently labeled for apple that have novel modes of action.
 - b. Test economical biological control agents to determine proper implementation procedures under Michigan conditions.
 - c. Identify efficacious material for the control of shoot and trauma blight.
2. Investigate fungicides to replace carbamate and B2 fungicides and for rotation with copper, strobilurin, and boscalid fungicides.
3. Develop programs to reduce reliance on single-site fungicides and to delay the development of resistance.
4. Evaluate efficacy and economics of alternate row vs. full cover fungicide applications.
5. Screen for strobilurin and boscalid resistance.
6. Continue evaluation of breeding potential for genetic traits in apple that could confer rootstock and cultivar resistance to fire blight and scab.
 - a.) Identify resistance genes that could be introduced to desirable cultivars.
7. Implement new cultural practices, including strategies of orchard floor management that enhance disease control.
8. Develop and implement new fungicides and biological control agents for post-harvest disease control.

Weeds, orchard floor, and soil pest management

1. Evaluate and implement new weed physical, chemical and biological control strategies, tactics and tools.
2. Evaluate and implement compatible ecological systems that favor pollination, biological control and sustainability.
3. Evaluate and implement orchard floor systems that manage weeds while providing habitat favorable to development of beneficial soil organisms.

Pollination

1. Develop and implement pollination strategies and tactics that are compatible with pest management (pollination/natural enemy plant strips, alternate row mowing, etc.).

Wildlife

1. Develop and implement alternatives for deer management (e.g. fencing and repellents).
2. Develop and implement alternatives for control of mice and voles.

Horticultural (Including physiological disorders)

1. Evaluate breeding potential for genetic traits in apple that could confer rootstock and cultivar resistance to reduce or eliminate physiological disorders.
2. Evaluate orchard systems and new production technologies.

3. Evaluate new materials and strategies for growth regulation (i.e., apple thinning, shoot growth, etc.).
4. Develop better understanding of nutritional disorders (eg., bitter pit).

Regulatory

1. Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
2. Michigan needs to be on a level playing field with national competition when it comes to chemical restrictions. EPA must take a regional perspective in developing and implementing regulatory needs.
3. Facilitate, engage and increase funding to the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacement insecticides and viable fungicides and bactericides. Current priorities are:
 - a. Kasugamycin
 - b. Gentamicin
3. Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.
4. Ensure nursery stock is virus-tested for all known viruses.
5. Implement and fund enforcement of laws regulating neglected orchards.
6. Increase cost sharing for implementation of IPM technologies (weather and others).
7. Construct and maintain endangered species maps and endangered species corridors that are reasonably precise (township level).

Education

- Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- Improve delivery of real-time pest management information to the agricultural community.
- Offer apprenticeship programs for scout training.
- Help develop and educate a healthy private consultant industry.
- Inform landowners about issues and laws regulating neglected orchards.
- Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.
- Provide hands-on educational opportunities for regulators and policymakers.

Development of an Apple Pest Management Strategic Plan

Background

- Michigan annually ranks third in production of apples in the U.S. with an annual average of 19.7 million bushels (827 million pounds) for the five-year period from 2002-2006.
- The average value of production during the years 2002-2006 was \$96,052,000 per year. Apples have an economic impact of ~\$700 million annually.

- Over 7.6 million trees are planted on nearly 950 farms comprising approximately 37,000 acres of orchard (MASS 2007).



- The average utilization of Michigan apples during 2002-2006 was 34.5% for fresh market and 65.5% for processing. About 11% of Michigan's process apples are used by the baby food industry. Michigan is home for Gerber Products, the baby food industry leader accounting for 83% of the market.
- Michigan is the nation's leading supplier of apple slices for makers of frozen apple pies, pie filling, and new fresh-cut slices used for snacks and salad products.
- Most of the state's apple production occurs within the Great Lakes Basin. Some orchards are established on permeable soils and within ecosystems that are home to one or more threatened and endangered plant or invertebrate species.
- The top five apple producing counties are Kent with 8,150 acres, Berrien with 4,200 acres, Van Buren with 3,300 acres, Ottawa with 3,500 acres and Oceana with 3,250 acres.
- Climate and pest complex and pressure vary between the different apple producing regions, presenting challenges in formatting statewide IPM strategies.
- Apples are also grown commercially in 32 other counties across the lower peninsula, including the fringes of the Detroit metropolitan area. Many small orchards exist throughout the state that produce apples for local uses that are not within these major growing areas.
- The top five apple varieties in total acres were Red Delicious, Golden Delicious, Jonathan, Ida Red and Gala. 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 twelve months or more and come out with virtually just-harvested quality.
- Apple trees take four to five years simply to mature and about 10 years before the tree reaches its maximum yield.
- Apples are grown mainly in the hilly terrain area of 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.
- Very few orchards receive supplemental irrigation as the fruit growing areas receive an average of 27" of rainfall per year. Michigan's humid, wet climatic conditions are often accompanied by a significant risk of orchard disease infections.
- With a strong background in fruit and vegetable production, Michigan is the nation's fourth-largest employer of migrant workers (*ca.* 45,000 annually). Since every single apple is harvested by hand over 2.5 months, Michigan growers are proactive in worker protection practices and measures. The apple industry in MI is dependent on a reliable migrant labor force to produce and deliver its crop annually.
- Pruning and hand thinning are important cultural practices to grow apples. The shape of the tree has to be modified to ensure sunlight can get through to the inner branches.
- Pruning is done during the winter months and early spring, with summer pruning taking place in August in vigorous high density blocks. Fruit thinning is an annual practice. Pre-harvest growth regulator applications to enhance fruit color and harvesting are also used in some blocks.
- All apple growers chemically and/or hand thin their crop. Apples would have biennial bearing, smaller fruit size and very large labor costs if apples were thinned exclusively by hand.

Important Pest Management Issues

Managing apple pests is an especially daunting task in Michigan relative to other states. This Midwest production area appears to be a crossroads for all of the major pests of apple found in the western and eastern US. Furthermore, the variety of native and agricultural habitats adjacent to Michigan apple orchards serves as a constant source of colonizing pests. The diversity of pests and their continuous influx from bordering areas provide unique challenges to narrow-spectrum technologies, such as mating disruption. Over 25 kinds of insects and mites may need to be controlled in Michigan orchards. It is critical that at least a dozen pests that directly feed on the crop be effectively controlled to maintain adequate yields of quality fruit that is acceptable to consumers.

Key pests include the codling moth, oriental fruit moth, obliquebanded leafroller, plum curculio and apple maggot. Collectively, if left unchecked, this pest complex could be expected to reduce marketable yield by up to 100%. Likewise, plant disease epidemics are common in Michigan apple orchards and are fueled by environmental parameters (high humidity and rainfall, hail events) that enhance pathogen growth and dissemination. Left unchecked, diseases such as apple scab can cause significant fruit infections and fire blight can reduce marketable yield by killing blossoms and can also kill trees affecting the long-term stability of orchard blocks.

Weeds provide a challenge to accomplishing production goals of annual high yields of high quality fruit required to remain profitable and compete in a global market. Weeds compete with trees for nutrients and water, provide habitat for pest populations, competition for pollination and can block access to the trees. Left unmanaged, weeds can reduce productivity up to 60% if not controlled adequately.

Historically apple growers have responded to pest management challenges by adopting innovative integrated pest management (IPM) and other cultural practices that reduce pesticide use, improve operator safety, and protect the environment, yet maintain the stringent quality standards demanded by the marketplace. This apple pest management strategic planning process was initiated by the industry to help identify and prioritize the need for alternatives to replace pesticide control tools (initial focus on organophosphate and carbamate insecticides, and fungicides classified as B2 carcinogens) at risk due to the above factors. New USEPA restrictions (2006) on the use of the organophosphorous insecticide, azinphosmethyl, phases out use of this commonly used OP by 2012. Strategic planning and effectively addressing pest management issues that impact industry viability should help the apple industry continue to deliver the quality fruit demanded by the marketplace.

Michigan apple growers have accelerated efforts to develop and implement economically and environmentally sound pest management practices. They are engaged in a variety of activities designed to improve apple production using the best techniques available and to reduce pesticide impacts. Among the IPM practices being successfully implemented to varying degrees by Michigan apple growers are those listed below:

- Conservation of natural enemies: Organophosphate-resistant mite predators have proven effective in maintaining phytophagous mite populations at tolerable levels and have become a mainstay of IPM in apples in Michigan. Growers diligently conserve predator

- Orchard scouting for insect pests and beneficials: Growers commonly use moth catches in pheromone traps and degree-days models to monitor adult moth activity and better time spray applications.
 - Scouting for larvae and eggs is also used to determine the timing and need to apply controls for some key pests, such as obliquebanded leafroller.
 - Many growers routinely monitor apple maggot adults with yellow sticky traps or sticky red spheres and spray only when, and if, adults are captured. Another management tactic used by some growers is border row (perimeter 4-6 rows) applications of pesticide to intercept immigrating apple maggot adults.
- Weather monitoring for optimized timing of controls for insect and disease pests.
- Use of web-based disease forecasting tools (Enviroweather).
- Alternate row spraying.
- Border and partial block or "hot-spot" spraying.
- Use of air-curtain and "smart" sprayers.
- Use of *MSU Crop Advisory Team newsletters* (ca. 800 weekly viewers per issue; internet and print).
- Increased use of selective and "softer" materials.
- Pheromone-based mating disruption.
- Orchard sanitation--removal of sources of pests.
- Resistance management.
- While all growers have not adopted all IPM practices, implementation by many has contributed to industry-wide pesticide reduction. For example, adoption of IPM strategies during the 1980s was correlated with a 40% reduction of spray applications. Growers embrace new techniques that result in less pesticide usage when it is demonstrated that effective pest management techniques are available and when it is economical to do so.

Although the Michigan apple industry promotes ecological diversity and supports conservation efforts protecting endangered species, the Endangered Species Act as currently codified by the USEPA is a major concern. Reliance on www-based maps and computer-based, six month label updates is not workable. Before producers can be held responsible for protecting endangered species, maps and endangered species corridors must be constructed and maintained that are reasonably precise (township level). This will provide growers with the knowledge and tools necessary to provide capable stewardship that is compatible with production concerns.

The Michigan apple industry initiates and supports a variety of research projects through a program authorized by a Michigan law that allows growers to tax themselves to generate funds. The MAC assessment generates over \$250,000-\$270,000 annually for research. These funds are used to support an array of production and pest management projects considered most critical for the future of the apple industry and annual support of the Michigan IPM Alliance. The IPM Alliance is a consortium of fruit and vegetable commodity groups, processors, the Michigan Department of Agriculture and Michigan State University that is dedicated to increasing implementation of IPM in Michigan.

Research funds available through the MAC the MSHS, MI Project GREEN (Generating Resources for Economics, Education, and the Environment), and private industry to address critical pest management issues are limited. The Michigan Agricultural Experiment Station (MAES) supports 4 fruit research stations (Clarksville Horticultural Experiment Station, Clarksville; Northwest Michigan Horticultural Research Station, Traverse City; Southwest Michigan Research and Extension Center, Benton Harbor; and Trevor Nichols Research Complex, Fennville). The MAES, in conjunction with private and public agencies (Michigan Department of Agriculture, EPA, USDA), initiates and supports many IPM related research projects. A state initiative, Project GREEN, has provided funds in excess of one million dollars on apple IPM projects. Many research/demonstration projects combine ‘state of the art’ and experimental IPM protocols to dramatically reduce reliance on broad-spectrum pesticides in the apple. These research/demonstration projects have been designed to teach researchers and growers what may/may not be possible in this arena.

A range of agricultural consultants and suppliers serve Michigan apple growers. There are several independent integrated pest management consultants that contract apple acreage in Michigan. Not surprisingly, where private consultants have been established for some time, more growers tend to use their services and to utilize more intensive IPM than growers in regions where private consultants are relatively few in number and/or recently established. Input suppliers contact most, if not all, apple growers on at least a periodic basis. Several input suppliers provide scouting services, as well.

MSU Extension fruit and IPM agents have made a significant effort to educate growers about IPM strategies and protocols. MSUE works closely with private sector consultants, providing training and information. Some examples follow:

- A biannual 2 to 3-day “Fruit IPM School” trains over 100 consultants, scouts and growers in the principles and practices of fruit IPM.
- “Statewide IPM Updates”, field identification and training sessions help update scouts and consultants about current and developing events during the growing season.
- MSUE agents also hold regional breakfast and evening meetings to keep local consultants and growers apprised of developments in their areas.
- MSU has established the Fruit Area of Expertise Team (AOE) comprised of the campus and field-based research and extension specialists to enhance MSUE's ability to respond to growers’ needs on a broad range of pest, production, and marketing problems.
- The fruit AOE and private consultants participate in a weekly conference call to discuss conditions and appropriate IPM strategies. This "Crop Advisory Team" (CAT) publishes the CAT Alert Newsletter, which is viewed weekly by ca. 800 people (2007).

Organic Apple production in Michigan

While increasingly demanded in the retail marketplace, organic production of apples has long been a challenge in the entire Eastern US. Over the last two decades, the apple industry has seen dramatic reductions in the pounds of active ingredient chemistry used, in large part due to widespread adoption of IPM. Yet controlling fungal diseases, in particular, remains very difficult owing to frequent rainfall and high humidity.

Market conditions demand Eastern apple growers take another look at the opportunity. Demand for processed organic apple products is occurring with virtually every retail account, and the fresh market demand for organic Eastern-grown apples is also very strong.

In 2006-07, the Michigan Apple Committee initiated USDAS-funded research on the Economic Feasibility of Organic Apple Production in Michigan. The report appeared to show economic opportunities that could allow organic production in Michigan and the rest of the East, which will have much higher production costs, crop loss levels and risk than conventional apple production.

Following up on this promising finding, MAC hopes to further assist Michigan growers in deciding whether to implement some organic apple production, by possibly seeking funding in the 2008 Farm Bill for relevant next-step research projects.

Justification and Possible Benefits to the Michigan Apple Industry

An apple pest management strategic plan document can help the industry identify the need for alternatives to replace pesticide control tools at risk due to resistance, regulatory, or consumer-driven pressures. Further, a transition strategy should help position the apple industry more favorably (through strategic planning for future pest management needs) to pursue funding to address research and education needs identified through the process.

More information and new techniques are necessary if apple growers are to continue to address critical pesticide issues and to explore alternative management systems that reduce reliance on FQPA-targeted pesticides, address resistance issues, etc. A few newer, more selective, tactics and tools are being developed for tree fruit pests; however, their performance under Michigan conditions is not well defined. The variety of native and agricultural habitats adjacent to apple orchards and the diversity of pests that may colonize these orchards provide unique challenges to narrow-spectrum technologies, such as mating disruption and other selective strategies. In some situations, on-farm research provides the best opportunity to determine proper timing of certain products and other more selective strategies and chemistries.

Summary of Planning Process

The overall goal of the pest management strategic planning process is to actively identify and prioritize regulatory, research, and educational needs for addressing critical pesticide and pest management issues, exploring effective alternative management systems that reduce reliance on FQPA-targeted pesticides, address resistance issues, and other relevant industry concerns, as appropriate.

The specific objective of the planning process is to develop a document that will provide the foundation for a pest management strategic plan that will: a) effectively and economically address pest management issues that impact industry viability, and b) lessen dependency on organophosphate and carbamate insecticides and B2 fungicides in apple production.

Work Plan

Development of a Pest Management Strategic Plan for Michigan Apples, as envisioned by the industry, will be accomplished in a series of steps. A committee consisting of Michigan apple growers, Michigan State University Extension specialists and educators, and representatives of the Michigan Apple Committee, Michigan Processing Apple Growers, Michigan Agricultural Cooperative Marketing Association, Inc., the Michigan State Horticultural Society, and the Michigan Farm Bureau will gather in a series of Winter and Spring meetings in 2008 to review and revise a PMSP document originally begun in 2000. The Michigan Apple Research Committee (now called the MI Apple Research Subcommittee) recommended to the MI Apple Committee that the development of the 2000 PMSP be funded, and the Michigan Apple Task Force unanimously approved the proposed process and framework for development of an apple strategic pest management plan on March 21, 2000. It was agreed that document development would be guided by the following principles:

1. Profitability for apple growers will be the key element of the strategic plan; cost-effective alternative pest management tools and programs are needed.
2. Geographical regions within Michigan will be considered when developing strategies due to differences in environmental/climatic conditions, production practices, pest complex and pressure, crop varieties, and marketing opportunities.
3. A major outcome of the document will be to identify and prioritize research areas, regulatory actions, and educational programs required as apple growers move toward greater reliance USEPA reduced risk pesticides and new technologies.
4. Pest management programs will consider worker protection, food safety, endangered species, and environmental/ecological issues.
5. The completed plan will have the broad support of the Michigan apple industry.

Format of the Strategic Plan

The first part of the document is a brief description of the industry, its pest management issues and priorities, and a summary of the pest complex and its impact on apple production. A bulleted list of IPM priorities for research, regulatory and educational needs of the industry, as identified by growers and other members of the fruit industry, is positioned at the front of the document. The foundation of the strategic plan is a pest-by-pest analysis of the current role of older and newer chemistries and other pest control options and management strategies in Michigan apple production systems. The focus is on the 12 key insect and 9 key disease pests that are principally controlled by these materials. The "TO DO" list for each pest identifies what needs to be accomplished in terms of registrations, research, and education in order to develop pest management programs with greater reliance on more selective tactics.

Pest Biology for Key Pests

Pest complex

This section summarizes the biology of key apple pests that are principally controlled by pesticides for insect and disease control. Each is a major pest of apple in Michigan because it directly injures the fruit and makes it unmarketable or damages foliage and woody tissue in a manner that can kill the tree. Another dozen or so pests of apple are not covered because they are either sporadic pests or feed primarily on apple foliage and are principally controlled by other classes of pesticides (e.g., mites by various miticides).

Secondary Insect Pests Not Summarized in This Document:

1. European red mite
2. Twospotted spider mite
3. Apple Rust Mite
4. White apple leafhopper
5. Potato leafhopper
6. Redbanded leafroller
7. Variegated leafroller
8. Tufted apple bud moth
9. Eyespotted bud moth
10. Spotted tentiform leafminer

Major pests of apple in Michigan

❖ Codling moth (CM)

- Codling moth is the most important pest of apples in Michigan. This is a primary feeder within apples that makes the fruit unmarketable. Without effective control, losses can range from 50 to 90% of the crop.
- There are two generations in Michigan, with a partial third generation in exceedingly warm years.
- The insect overwinters as a mature larva with the adult emerging around full bloom. The adult lays eggs on the fruit and when the egg hatches the larva burrows into the apple creating large tunnels. After feeding within the apple for approximately three weeks, the larva emerges and seeks a pupation site. After two to three weeks in the pupal stage the adult emerges for a second generation.
- Second-generation larvae cause most of the damage. The peak emergence is typically the middle of August. The same infestation cycle is repeated, with the pupa overwintering until the next spring.

❖ Oriental fruit moth (OFM)

- Oriental fruit moth is generally considered a more serious problem in peach than in apple. In recent years, however, it has become a major pest of apples in Michigan and throughout the eastern United States. In southwest Michigan, the incidence of oriental fruit moth infestations in apples appears to be similar to codling moth infestations.

- Peach orchards in the vicinity will increase the chance of infestation but oriental fruit moth can be a serious problem in apple orchards when there are no nearby stone fruit orchards.
- There are three full generations and occasionally a partial fourth generation in Michigan.
- The first generation larvae bore into apple shoots. Subsequent generations feed within the apple and make the fruit unmarketable.
- The last generation is especially problematic as larvae hatch from mid-August to mid-September. This generation occurs near or during harvest and is the major cause of wormy fruit, often with little or no sign of injury.

❖ **Obliquebanded leafroller (OBLR)**

- The obliquebanded leafroller has become of major concern in recent years, due to its development of resistance to organophosphate insecticides in the major apple growing regions.
- This pest lives in a variety of crop and non-crop habitats. Obliquebanded leafroller infests apple, pear, cherry, plum, peach, rose, raspberry, gooseberry, currant, strawberry and many weeds.
- Damage from overwintering larvae occurs primarily during the pre-bloom to bloom period. This first group of larvae feed on floral parts destroying the fruit buds. Most fruit damaged at this time drop from the tree before harvest.
- In late July the larva of summer generation can be found feeding actively on growing terminals and on fruit where they feed underneath a protective covering of leaves. Summer feeding injury leaves the fruit unmarketable and can result in over 50% crop loss.

❖ **Plum curculio (PC)**

- Plum curculio is one of the most important insects attacking tree fruits.
- Adults typically migrate into orchards from adjacent woodlots in the spring around bloom time (early May).
- Curculio dispersal from overwintering sites to orchards is most reliably linked with either a maximum daily temperature of 75 °F for two to three days, or a mean daily temperature of 55-60 °F for three to six days.
- Spring migration lasts about six weeks. Peak activity and the critical time for control of plum curculio is during a 2-3 week period beginning at petal-fall.
- The adult lays an egg under the skin of the fruit leaving a crescent-shaped scar on the surface of the apple. In apple most eggs do not hatch, so the damage is cosmetic to the fruit surface.
- When the larvae do hatch, they burrow throughout the apple creating brown trails. After several weeks the larva emerges from the apple and falls to the ground where it pupates until late summer.
- Summer adults feed on the fruit surface.
- The resulting damage from the internal feeding, egg laying and adult feeding make the fruit unmarketable. Damage from this pest can range from 50-90% without control and commonly infest 100% of the backyard fruit trees.

❖ **Apple maggot (AM)**

- A native pest that feeds on a variety of fruit, has essentially no natural enemies, and will thrive in an abandoned orchard setting.
- Processors and fresh shippers have zero tolerance for apple maggot infested fruit, because of the distasteful flavor and odor left in the apple after feeding by the apple maggot larvae.
- The adult fly emerges in early July and lays eggs within the apple.
- The apple maggot causes two forms of injury. The flesh surrounding a puncture where eggs are deposited in immature fruit often fails to grow with the rest of the apple and becomes a sunken, dimple like spot in the surface. 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.
- Fruit infested are unmarketable and a zero tolerance for damage exists for export purposes.
- Controls for apple maggot have traditionally been spray applications on 8-10 day intervals to kill adults before they oviposit in the apple.
- Damage from the apple maggot can reach 50-100% if left uncontrolled. Due to the zero tolerance, effective controls are essential.

❖ **Speckled green fruitworm (GFW)**

- Speckled green fruitworm has one generation per year.
- Pupae overwinter in the soil and adults emerge starting in very early spring.
- Egg hatch occurs at the 1/2-inch green stage of bud development.
- Larvae feed on leaves, buds and developing fruit. Feeding on fruit results in deep, corky scars and renders the fruit unmarketable.

❖ **Rosy apple aphid (RAA)**

- Three generations of rosy apple aphid occur in Michigan.
- The first nymphs are present in the orchard when the trees are at 1/2-inch green. Feeding on foliage causes severe curling and twisting of growing shoots.
- The translocation of saliva from leaves to fruit results in stunted and deformed apples.
- Honeydew excretions provide a substrate for a black sooty fungus, which discolors fruit.
- Particularly susceptible varieties include Ida Red, Cortland, Rome and Golden Delicious.
- Treatments must be made early before the aphids are protected inside curled leaves.

❖ **Woolly apple aphid (WAA)**

- There are typically 3 to 4 generations of woolly apple aphid in Michigan.
- Aphids generally cluster in wounds on the trunk and branches of apple trees, as well as on root knots and underground parts of the trunk.

- Leaf axils on terminal shoots are preferred summer feeding sites.
- Subterranean wooly apple aphid may be present year round and can serve as a source of aerial infestation starting in the spring.
- Injury includes gall formations that increase in size from year to year as the aphids feed. The buildup of galls on young trees effects water and nutrient uptake and reduces tree growth.
- High populations can result in fruit discoloration from the growth of a black fungus on aphid honeydew excretions.

❖ **San Jose scale (SJS)**

- There are two generations of San Jose scale per year in Michigan.
- This pest multiplies very rapidly and attacks tree bark, leaves and fruit.
- Scale feeding on woody tissue results in a decline in tree vigor, growth and productivity and if left unchecked, will kill twigs, limbs and eventually the tree.
- Scale infestations of the fruit causes a distinctive reddish-purple spotting that results in fruit downgrading or culling.

❖ **Tarnished plant bug (TPB)**

- Three to five generations per year occur in Michigan.
- Adult tarnished plant bug feed on flower buds beginning in early April, doing most damage around bloom.
- Damaged buds exude a gummy liquid and shrivel up.
- Adults also oviposit into and feed on young fruit, resulting in pitted, deformed fruit.

❖ **Japanese beetle (JB)**

- The Japanese beetle overwinters as a larva in the soil.
- Adults are the only life stage that feed in apple.
- Beetles emerge in mid-June to July, fly to orchards and feed on foliage, skeletonizing large amounts of leaf tissue.
- Fruit feeding is less common, and usually occurs if the fruit has been previously damaged or is over mature. Most damage occurs late in summer or early fall.

❖ **Dogwood borer (DWB)**

- Adult emergence of dogwood borer begins in mid-June and continues into August.
- Eggs are primarily deposited in or near burr knots that form at the graft union on dwarfing and semi-dwarfing rootstocks.
- Larvae develop in shallow tunnels within the burr knots. Damage to the trunk reduces tree growth.
- Severely infested trees are killed.
- Dogwood borer is a chronic pest on rootstocks that have a high propensity to form burr knots, Mark, M9 and M26. Approximately 70% of new orchards in Michigan are planted on one of these stocks.

Other pests (break apart into individual pests): In addition to the 12 key pests discussed above, there are at least another dozen kinds of arthropods that are of economic concern to Michigan apple growers. These pests are either a sporadic problem or feed primarily on apple foliage and, at high infestation levels, indirectly affect fruit harvest.

- ❖ Apple mites, particularly the European red mite and the two-spotted spider mite are annual pests on apple leaves and severe infestations can lead to tree defoliation and premature fruit drop. The most serious injury occurs in the early summer, when trees are producing fruit and buds for the following season.
- ❖ Leaf sucking insects, such as aphids and leafhoppers, are frequently present in apples and occasionally reach numbers that indirectly reduce fruit size and overall tree vigor.
- ❖ Spotted tentiform leafminer, is always present as a foliar pest, but at high infestations can reduce fruit size and enhance premature fruit drop.
- ❖ Other insects may feed on apple fruit, but often do not require controls targeted specifically for them. The status of many of these pests is likely to increase if growers are forced to increase use of broadly toxic, synthetic pyrethroids, for control of key pests.

Outline of the Apple Pest Management Strategic Plan

FOUNDATION OF STRATEGIC PLAN

The remainder of this document is a pest-by-pest analysis of the current role of organophosphates (OP's), carbamates (CB's) and pyrethroids, future pest control options, and the use of other pest management aids (cultural and otherwise), in Michigan apple production systems. Again, the focus is on the 12 key pests that are principally controlled by these materials. The "TO DO" list for each pest identifies what needs to be accomplished in terms of registrations, research, and education in order to develop pest management programs with greater reliance on more selective tactics.

1. Codling moth (CM)

- ❖ The most common internal feeding worm in apple.
- ❖ Major target of OP insecticides for close to 50 years
- ❖ Resistance to OP insecticides has been detected in all of Michigan's major apple production regions.
- ❖ Several insecticides that are effective OP alternatives for CM control have been registered over the past five years, however they are generally twice as expensive as the older insecticide chemistries
- ❖ To limit costs growers often rely on synthetic pyrethroids for CM control that can result in the disruption of current IPM programs.
- ❖ Zero tolerance for wormy fruit, which are unmarketable and fruit rot will spread in storage.
- ❖ Entire truckloads of fruit have been rejected when wormy fruit has been detected.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Widely used insecticide for control of CM.
 - Highly effective against susceptible populations with up to 2 weeks of residual activity depending on weather.
 - Field failures have occurred and resistance in all Michigan apple production regions has been documented.
 - Use is complicated by the long REI's of 14 days for general activities and 60 days for u-pick operations.
- ❖ Phosmet (Imidan)
 - Sister product of Guthion, use has increased as a result of increased restrictions on the use of Guthion
 - Effective control, but requires more applications than Guthion because of shorter residual.

- Efficacy negatively impacted by high pH water, thus more difficult to use.
 - Currently, common option near harvest because of shorter PHI relative to Guthion.
 - Reported to be easier on beneficials than other OPs.
 - Same mode of action as Guthion, thus resistant populations are likely to be present in Michigan.
- ❖ Chlorpyrifos (Lorsban)
 - Was highly effective against CM populations that are resistant to Guthion and Imidan, but no longer labeled for use after petal-fall
 - Petal-fall application may provide some control by killing early emerging adults.

Other insecticides currently registered

- ❖ Carbaryl (Sevin)
 - Effective insecticide if used at full rate per acre.
 - Expensive option at full rate.
 - Short residual (less than 7 days), many applications required for season-long control.
 - Toxic to beneficial insects, bees, and mites and disruptive to established IPM programs.
 - Processor restriction, zero tolerance, thinning only.
 - Essential major thinner after bloom at ¼ of insecticide rates.
- ❖ Methomyl (Lannate)
 - Short residual.
 - Late season option due to Short PHI.
 - Effective insecticide if used at full rate per acre.
 - Very short residual (less than 7 days), many applications required for season-long control, too expensive to spray at 3-4 day intervals.
 - Toxic to beneficial insects, bees and mites and disruptive to established IPM programs.
- ❖ Pyrethroid insecticides, including Permethrin (Pounce and Ambush) Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max).
 - Relatively short residual, many applications required.
 - Post-bloom use may upset IPM programs by destroying beneficial mites and insects.
 - Cross-resistance with OP-resistant CM populations has been documented.
 - Very economical and use is increasing.
- ❖ Novaluron (Rimon)
 - A highly effective insecticide for CM control.
 - Proper use requires accurate timing using degree-day model.

- Good resistance management practice limits use to one generation per season.
 - IGR with novel mode of action makes it a good resistance management option.
 - Twice as expensive as older chemistries.
 - Additional cost concerns due to limited pest spectrum.
- ❖ Pyriproxifen (Esteem)
 - IGR that is only a fair CM control, timing is critical (has to be on foliage prior to egg laying).
 - Limited use after first generation CM because of long PHI (45 day) and reduced efficacy.
 - Cost prohibitive.
 - Limited use due to above issues.
- ❖ Acetamiprid (Assail)
 - A highly effective insecticide for CM control.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - Twice as expensive as older chemistries.
- ❖ Thiacloprid (Calypso)
 - A highly effective insecticide for CM control.
 - A good option for CM control, as it is also effective against other important pests, including aphids and apple maggot.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - Twice as expensive as older chemistries.
- ❖ Clothianodin (Clutch)
 - Provides good control of first generation CM, but not effective second generation.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - Twice as expensive as older chemistries.
- ❖ Methoxyfenozide (Intrepid)
 - Effective if pest pressure is low to moderate.
 - High rates and multiple applications required.
 - Cross-resistance with OP-resistant CM populations has been documented.
 - Expensive.
- ❖ Tebufenozide (Confirm)
 - Less effective than the closely related compound, methoxyfenozide.
 - High rates and multiple applications required.
 - Expensive.
- ❖ Spinetoram (Delegate)
 - A highly effective insecticide for both first and second generation CM control.
 - New in 2008; likely to be expensive.

- ❖ Spinosad (Spintor)
 - Spinosyn-based compound that is substantially less effective than spinetoram (Delegate).
 - High rates and multiple applications required.
 - Another formulation of spinosad, Entrust, is organically approved.
 - Expensive.
- ❖ Emamectin benzoate (Proclaim)
 - Effective insecticide for first generation CM control, not effective for second generation.
 - Best results are achieved at the high label rate.
 - Excellent timing and coverage are required to achieve control.
 - Novel mode of action makes it a good resistance management option.
 - Expensive.
- ❖ Rynaxypyr (Altacor)
 - A highly effective insecticide for both first and second generation CM control.
 - Novel mode of action makes it a good resistance management option.
 - Newly registered in 2008; likely to be expensive.
- ❖ Indoxacarb (Avaunt)
 - Small-plot and on-farm research conducted in Michigan indicates only fair-good activity against CM.
 - Limited pest spectrum makes this an expensive option for CM control.
- ❖ Kaolin (Surround)
 - Limited suppression of CM only.
 - Does not meet zero tolerance requirement.
 - Lack of rain fastness may limit usefulness in Michigan.
 - Concerns with physiological effects on plants.
 - Thorough coverage necessary and problems with coverage at lower gallonages.
- ❖ Mineral oils (light summer)
 - Primarily affects eggs, suppression only.
 - Compatibility problems when tank mixed with certain fungicides.
 - Phytotoxic problems on certain cultivars in certain weather conditions.

Non-chemical options

- ❖ Pheromone-based mating disruption
 - Costly and generally used in combination with insecticide sprays.
 - Appears to be less efficacious in this region than in the Western U.S. due to 1) orchard configuration (long and narrow), 2) influx of high numbers of CM from adjacent habitats (abandoned orchards and wild hosts) and 3) the usefulness of pheromone for control of

codling moth is negated if mandatory sprays for plum curculio, OFM and apple maggot are going to control codling moth anyway.

- However, a whole-farm or area-wide approach has proved to be an especially effective means of using mating disruption in Michigan.
 - An estimated 7000 acres were treated with pheromone in 2007.
 - A good resistance management approach and does not negatively impact beneficials.
 - Should not be used without a scouting program.
 - Not a stand alone approach.
- ❖ Codling moth granulosis virus
- Biological insecticide that is specific to codling moth.
 - Provides fair to good control of this pest.
 - Very short-lived, repeat applications needed.
 - Used only as part of a CM management program, as 7-10 applications per generation would be needed to achieve control with virus alone.
 - Formulations are approved for organic use.

Unregistered chemicals or other control materials

- ❖ Flubendiamide (Belt)
- Effective CM control that should be registered soon.
 - Novel mode of action (same as rynaxypyr) makes it a good resistance management option.
 - Registration anticipated in 2008; Likely to be expensive.

Pest management aids

- ❖ Pheromone trapping to determine the need and timing of control actions.
- ❖ Degree-day modeling is critical.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Michigan needs to be on a level playing field with national competition when it comes to chemical restrictions. EPA must take a regional perspective in developing and implementing regulatory needs.

- ❖ Expedite registration of new insecticides and other control tactics as they become available.
- ❖ Maintain registration of azinphos-methyl beyond its targeted withdrawal date of 2012.
- ❖ Endangered species maps and endangered species corridors must be constructed and maintained that are reasonably precise (township level).
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration. (different than the EUP program as this doesn't work).

Research needs

- ❖ Determine effectiveness of new insecticides such as indoxacarb, methoxyfenozide and thiacloprid.
- ❖ Evaluate new mating disruption delivery systems and assess the usefulness and economics of this technology in Michigan.
- ❖ Develop and implement management programs that combine the use of mating disruption and selective 'soft' chemistries such as indoxacarb, methoxyfenozide and thiacloprid.
- ❖ Make on farm research monies available.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

2. Oriental fruit moth (OFM)

- ❖ In some regions of Michigan OFM is the most common internal feeding worm in apple.
- ❖ Often held in check by broad-spectrum materials targeted against other key pests (e.g., CM, PC & AM).
- ❖ 1st generation larvae feed in shoots and generally do not infest fruit.
- ❖ Primarily a late-season target of OP insecticides in apple.
- ❖ The last generation attacks fruit late in the season at a time when insecticides often are not being applied for control of other pests.

- ❖ Major target of OP insecticides, rotation of OPs plays important part in resistance management.
- ❖ Several insecticides that are effective OP alternatives for OFM control have been registered over the past five years, however they are generally 2-3X more expensive than the older insecticide chemistries
- ❖ To limit costs, growers often rely on synthetic pyrethroids for OFM control, which can result in the disruption of current IPM programs.
- ❖ Zero tolerance for wormy fruit, which are unmarketable and will cause fruit rot to spread in storage.
- ❖ Entire truckloads and blocks of fruit have been rejected if wormy fruit has been detected.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Isolated field failures reported. Assays have not documented resistance to OP's. Could be timing problems.
- ❖ Phosmet (Imidan)
 - Isolated field failures reported. Assays have not documented resistance to OP's. Could be application timing problems.
- ❖ Chlorpyrifos (Lorsban)
 - Short residual, good control if population densities are low.
 - New label restricting post and bloom use no longer allows this product to be applied for control of active larvae.

Other insecticides currently registered

- ❖ Carbaryl (Sevin)
 - Effective if used at full label rate.
 - Short residual.
 - Highly toxic to beneficial insects.
- ❖ Pyrethroid insecticides, including Permethrin (Pounce and Ambush) Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max).
 - Relatively short residual, many applications required.
 - Post-bloom use may upset IPM programs by destroying beneficial mites and insects.
 - Very economical and use is increasing.
- ❖ Acetamiprid (Assail)

- A good insecticide for OFM control.
- One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
- Twice as expensive as older chemistries.
- ❖ Thiacloprid (Calypso)
 - A good insecticide for OFM control.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern
 - Twice as expensive as older chemistries.
- ❖ Methoxyfenozide (Intrepid)
 - A good insecticide for OFM control.
 - More expensive than older chemistries.
- ❖ Spinetoram (Delegate)
 - A highly effective insecticide for OFM control.
 - New in 2008; likely to be expensive.
- ❖ Spinosad (Spintor)
 - Spinosyn-based compound that is substantially less effective than spinetoram (Delegate).
 - High rates and multiple applications required.
 - Another formulation of spinosad, Entrust, is organically approved.
 - More expensive than older chemistries.
- ❖ Indoxacarb (Avaunt)
 - Small-plot and on-farm research conducted in Michigan indicates only fair-good activity against OFM.
 - Limited pest spectrum makes this an expensive option for OFM control.

Non-chemical options

- ❖ Pheromone-based mating disruption
 - Efficacious tactic for control of OFM.
 - Use is increasing where OFM has been identified as a key pest, however use continues to be limited in areas where pest pressure is low.

Pest management aids

- ❖ Pheromone trapping to determine the need and timing of control actions.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Expedite registration of new insecticides and other control tactics as they become available.
- ❖ Develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration (different than the EUP program as this doesn't work).

- ❖ Develop protocol whereby pesticide remains usable if residue analysis before consumption shows below tolerance.

Research needs

- ❖ Determine effectiveness of new insecticides.
- ❖ Understanding of ecology of this pest, especially movement from adjacent orchard and non-orchard habitats.
- ❖ Evaluate new mating disruption delivery systems and assess the usefulness and economics of this technology in Michigan.
- ❖ Develop and implement management programs that combine the use of mating disruption and selective 'soft' chemistries.
- ❖ Evaluate resistance, especially cross resistance of OP's and new chemistries.
- ❖ Residue and post-harvest interval studies.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

3. Apple maggot (AM)

- ❖ Major target of OP insecticides in mid-to-late summer.
- ❖ Two neonicotinoids, acetamiprid and thiacloprid, are the only effective alternatives to azinphosmethyl and phosmet
- ❖ Export demands for zero tolerance of larval infested fruit dictate need for extremely high level control programs.
- ❖ Most domestic processors and markets have zero tolerance.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Most widely used insecticide for control of AM.
 - Highly effective with up to 2 weeks of residual activity.

- Curative properties (back-action) against infesting larvae.
- 60 day PHI in U-pick operations precludes use.

❖ Phosmet (Imidan)

- Sister product of Guthion, second most widely used material for AM control.
- Effective control, but requires more applications than Guthion because of shorter residual.

Other insecticides currently registered

❖ Carbaryl (Sevin)

- Short residual, less effective than OP's.

❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)

- Short residual, multiple applications required.
- Thus, provides only fair to good AM control.
- Post-bloom use may upset mite management programs by destroying beneficial mites and insects.
- Not acceptable by some processors for AM.

❖ Acetamiprid (Assail)

- An effective insecticide for AM control.
- A good option for Michigan growers as it also provides summer control of CM and OFM.
- If used for early CM control then not available for AM control later in season.
- One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern. If used for early CM control then not available for AM control later in season.
- 2-3X cost of OP's.
- Shortest PHI (7 days).
- Currently, manufacturer is not supporting MRL's for Michigan's export markets.

❖ Thiacloprid (Calypso)

- An effective insecticide for AM control.
- A good option for Michigan growers as it also provides summer control of CM and OFM.
- If used for early CM control then not available for AM control later in season.
- One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern .
- 2-3X more expensive than older chemistries.

❖ Imidacloprid (Provado)

- A good insecticide for AM control.
 - However, not a good option for Michigan growers as it does not provides summer control of CM and OFM.
- ❖ Kaolin (Surround)
 - Shows promise in Michigan research trials.
 - However, requires frequent applications (10-19) and excellent coverage.
 - Additionally, lack of rain fastness may limit usefulness in Michigan.
 - Concerns with physiological affects on plants.
 - Thorough coverage necessary and problems with coverage at lower gallonages.
 - Difficult removal from fruit at harvest.
- ❖ Spinosad (Spintor)
 - Only moderately active against AM, provides suppression but less than adequate control.
 - Another formulation of spinosad, Entrust, is organically approved.
 - A bait spray formulation is registered (GF-120), but it is not effective under Michigan conditions of frequent precipitation and immigrating populations.
 - Short residual is a problem.
- ❖ Spinetoram (Delegate)
 - Only fair to good control achieved in small-plot research trials. Larger-block trials are needed to confirm whether it is an effective AM control or not.
 - Just recently registered, likely to be expensive.
- ❖ Indoxacarb (Avaunt)
 - Only fair control achieved in small-plot research trials, and doesn't provide summer control of CM.
 - More expensive than older chemistries.

Non-chemical options

- ❖ Mass-trapping on border rows; costly and not as effective as above control measures.

Unregistered chemicals or other control materials

- ❖ Pesticide-treated biodegradable spheres
 - Attractant & feeding stimulant plus imidacloprid mixed in paint.
 - Expensive and labor intensive.
 - Not likely a stand alone treatment.

Pest management aids

- ❖ Monitoring with attractant-baited traps to determine the timing of control actions.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Expedite registration of new insecticides and other control tactics as they become available.

Research needs

- ❖ Determine effectiveness of new insecticides.
- ❖ Pesticide-treated spheres and other attract-and-kill strategies.
- ❖ Improve reliability of traps to allow for use in determining the need to treat.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

4. Plum curculio (PC)

- ❖ Primary injury caused by adult plum curculio feeding on fruit or leaving crescent-shaped cuts in the fruit as they deposit eggs.
- ❖ Plum curculio is a difficult pest to control.
- ❖ Critical time for control for overwintering generation is during a 2-3 week period beginning at petal-fall.
- ❖ Attractant-baited traps can be used to monitor PC activity, but additional testing is needed before they can be used to make management decisions.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Most widely used insecticide for control of PC.
 - Highly effective with 2-plus weeks of residual activity.
 - Curative properties; provides some control of larvae after they have entered the fruit.
- ❖ Phosmet (Imidan)
 - Sister product of Guthion, second most widely used material for PC control.

Other insecticides currently registered

- ❖ Carbaryl (Sevin)
 - Short residual, poor control.
 - Disruptive to mite management programs by destroying beneficial mites and insects.
- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)
 - Short residual, multiple applications required.
 - Effective option to OP's, however, PC sprays are made after bloom and pyrethroid use at this time is likely to upset mite management programs by destroying beneficials.
 - Lack of rain fastness may limit usefulness in Michigan.
 - Only moderate efficacy in small plot trials.
- ❖ Indoxacarb (Avaunt)
 - An effective option for early season PC control.
 - 2-3X more expensive than older chemistries.
 - Must be used prior to neonicotinoids to avoid the effect of their antifeedant properties.
 - Requires 100 hours for lethal effect.
- ❖ Thiamethoxam (Actara)
 - An effective insecticide for PC control.
 - A good early-season option for Michigan growers, application of this compound at this timing for PC also controls rosy apple aphid.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a growing concern.
 - 2-3X cost of OP's.
- ❖ Acetamiprid (Assail)
 - An effective insecticide for PC control.
 - Best use of this compound for Michigan growers is for 2nd generation control of CM and summer AM (One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern).
 - 2-3X more expensive than older chemistries.
- ❖ Thiacloprid (Calypso)
 - Less effective neonicotinoid than Actara or Assail for PC control.
 - Best use of this compound for Michigan growers is for 2nd generation control of CM and summer AM (One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern).
 - 2-3X more expensive than older chemistries.

- ❖ Clothianodin (Clutch)
 - An effective insecticide for PC control.
 - Best use of this compound for Michigan growers is for 2nd generation control of CM and summer AM (One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern).
 - 2-3X more expensive than older chemistries.
- ❖ Kaolin (Surround)
 - Only provides suppression of PC.
 - Requires frequent applications to build up barrier layer; difficult under rainy spring conditions in Michigan.

Non-chemical options

- ❖ Mass-trapping on border rows; costly and not as effective as above control measures.
- ❖ Push-pull strategy (attract towards border); 4X more expensive to insecticide only treatments.
- ❖ Entomopathogenic fungi and nematodes may be effective alternatives but more research needed.

Pest management aids

- ❖ Attractant baited traps, but improved consistency and reliability is needed.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Expedite registration of new insecticides and other control tactics as they become available.

Research needs

- ❖ Determine effectiveness of new insecticides.
- ❖ Entomopathogenic fungi and nematodes may be effective alternatives but more research needed.
- ❖ Determine if IGR insecticides can provide PC control.
- ❖ Screening for new compounds is a priority.
- ❖ PHI and residue work for use in mitigation strategies.
- ❖ Develop population monitoring tools for determining spray timing and the need to treat.
- ❖ Identify attractants and pheromones for possible attracticide/monitoring programs.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).

- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

5. Leafrollers

Obliquebanded leafroller (OBLR)

Redbanded leafroller (RBLR)

Variegated leafroller (VLR)

Tufted apple budmoth (TABM)

Eyespotted budmoth (ESBM)

- ❖ Historically, leafrollers have caused significant economical losses for fruit growers, especially in the Fruit Ridge area north of Grand Rapids and in Southwest Michigan.
- ❖ Comprised of a complex of species, however, OBLR is the key leafroller pest in Michigan.
- ❖ Cause surface injuries to apple fruit, damaged fruit are culled.
- ❖ Controls applied both pre- and post-bloom.
- ❖ The propensity of OBLR to develop resistance is a major consideration in putting together management programs for this pest. Resistance to OP's and several other compounds has been documented.
- ❖ A prolonged emergence pattern extends control time.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Not effective in the southwest or ridge area due to resistance, suspected to still be effective in other regions in the state.
- ❖ Chlorpyrifos (Lorsban)
 - Reduced efficacy in the southwest or ridge area due to resistance, still effective in other regions in the state.
 - No longer labeled for post-bloom applications.
- ❖ Methomyl (Lannate)
 - Short residual, not very effective.
 - Reduced efficacy in the southwest or ridge area due to resistance, still effective in other regions in the state.

- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)
 - Short residual, many applications required for season-long control.
 - Reduced efficacy in the southwest or ridge area due to resistance, still effective in other regions in the state.
 - Post-bloom use may upset mite management programs by destroying beneficial mites and insects.
- ❖ Spinosad (Spintor)
 - Good efficacy at high rate.
 - Reduced efficacy reported in WA; likely due to widespread reliance on this insecticide.
 - Short residual, frequent applications needed.
 - 2-3X more expensive than older chemistries.
- ❖ Spinetoram (Delegate)
 - A highly effective insecticide for leafrollers.
 - Registered in 2008; likely to be expensive.
- ❖ Tebufenozide (Confirm)
 - Good efficacy at high rate.
 - Slower acting than traditional materials, growers need to learn optimal use pattern.
 - Cross-resistance to OP's in some regions of country, e.g., upper New York.
 - More expensive than older chemistries.
- ❖ Methoxyfenozide (Intrepid)
 - Good activity, more effective than sister-product, tebufenozide.
 - Cross-resistance to OP's in some regions of country, including some apple production regions in Michigan.
- ❖ Emamectin benzoate (Proclaim)
 - A highly effective insecticide for leafroller control.
 - A good option for Michigan growers as it also provides CM and OFM control.
 - Novel mode of action makes it a good resistance management option.
 - 2-3X more expensive than older chemistries.
- ❖ Rynaxypyr (Altacor)
 - A highly effective insecticide for leafroller control.
 - Novel mode of action makes it a good resistance management option.
 - A good option for Michigan growers as it also provides CM and OFM control.
 - Registered in 2008; likely to be expensive.
- ❖ Novaluron (Rimon)

- A highly effective insecticide for leafroller control. A good option for Michigan growers as it also provides CM and OFM control.
- IGR with novel mode of action makes it a good resistance management option.
- 2-3X more expensive than older chemistries.
- ❖ Pyriproxifen (Esteem)
 - An effective insecticide for leafroller control.
 - IGR with novel mode of action makes it a good resistance management option.
 - 2-3X more expensive than older chemistries.
- ❖ Kaolin (Surround)
 - Small plot trials suggest suppression of feeding, but not lethal.

Non-chemical options

- ❖ Pheromone-based mating disruption
 - Not effective as a stand-alone control, supplemental insecticide sprays are needed.
 - Expensive, cost-prohibitive as a preventative control.
- ❖ *Bacillus thuringiensis* (Dipel, Javelin, etc)
 - Good option for leafroller control.
 - However, effectiveness is temperature sensitive; often too cool in Michigan to allow for good efficacy.
 - UV sensitive with a short residual, multiple applications required.

Unregistered chemicals or other control materials

- ❖ Flubendiamide (Belt)
 - A highly effective insecticide for leafroller control.
 - Novel mode of action (same as rynaxypyr) makes it a good resistance management option.
 - Anticipated registration in 2008; Likely to be expensive.

Pest management aids

- ❖ Pheromone trapping and phenology models for timing of control actions.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Expedite registration of new insecticides and other control tactics as they become available.
- ❖ Develop and implement a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration (different than the EUP program as this doesn't work).

Research needs

- ❖ On-farm evaluation of new insecticides.
- ❖ Potential for biological control.
- ❖ Evaluate new mating disruption delivery systems and multi-species formulations.
- ❖ Develop and implement management programs that combine the use of mating disruption and selective 'soft' chemistries.
- ❖ Evaluate resistance, especially cross resistance of OP's and new chemistries.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

6. Green Fruitworm (GFW)

- ❖ Present early in the season.
- ❖ Primarily feeds on foliage, but also attacks blossoms and fruit.
- ❖ Effectively managed with non-OP materials.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Generally considered ineffective.
- ❖ Phosmet (Imidan)
 - Generally considered ineffective.
- ❖ Chlorpyrifos (Lorsban)
 - Most effective OP insecticide.

Other insecticides currently registered

- ❖ Methomyl (Lannate)
- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)
 - Economical to use.

- Early season use of pyrethroids will also control rosy apple aphid, adult spotted tentiform leafminer and tarnished plant bug.
- Post-bloom use of pyrethroids may upset mite management programs by destroying beneficial mites and insects.
- ❖ Spinosad (Spintor)
 - Effective insecticide for green fruitworm.
- ❖ Spinetoram (Delegate)
 - Likely effective insecticide for green fruitworm, needs testing.
 - Registered in 2008; likely to be expensive
- ❖ Tebufenozide (Confirm)
 - Likely to be effective, needs testing.
- ❖ Methoxyfenozide (Intrepid)
 - Likely to be effective, needs testing.

Non-chemical options

- ❖ *Bacillus thuringiensis* (Dipel, Javelin, etc)

Unregistered chemicals or other control materials

- ❖ Flubendiamide (Belt)
 - Likely to be effective, needs testing.
 - Anticipated registration in 2008; Likely to be expensive.

Pest management aids

- ❖ Orchard scouting program.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Evaluation of new insecticides.

- ❖ Potential for control by mating disruption, particularly with sprayable formulations.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

7. Rosy Apple Aphid (RAA)

- ❖ A majority of orchards receive a pre-bloom insecticide application for control of this pest.
- ❖ Feeding on foliage causes severe curling, twisting, and abscission of growing shoots.
- ❖ Honeydew excretions provide a substrate black sooty fungus that discolors fruit.
- ❖ The translocation of saliva from leaves to fruit results in small and deformed apples.
- ❖ OP's will control other pests, such as San Jose Scale (SJS), if present at time of RAA sprays.

Organophosphate insecticides

- ❖ Chlorpyrifos (Lorsban)
 - Widely used insecticide for control of RAA.
- ❖ Diazinon
 - Limited use.

Other insecticides currently registered

- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)
 - Economical to use.
 - Pyrethroids are only moderately effective in controlling RAA.
 - Pyrethroids are not effective against scale so a tank mix of pyrethroids plus oil is needed to control RAA and SJS.
 - Pyrethroids should be used before European red mite eggs hatch and/or before mite predators are in the trees; post-bloom use may upset mite management programs by destroying beneficial mites and insects.

- Early season use of pyrethroids will also control climbing cutworms, adult spotted tentiform leafminer and tarnished plant bug.
- ❖ Endosulfan (Thiodan)
 - Use of oil plus endosulfan is needed to control both RAA and SJS.
 - This is a very effective control for RAA.
- ❖ Pyriproxifen (Esteem)
 - Will also control SJS if present at time of RAA sprays.
- ❖ Imidacloprid (Provado)
 - An effective insecticide for RAA control.
- ❖ Thiamethoxam (Actara)
 - An effective insecticide for RAA control.
 - A good early-season option for MI growers, as this compound also controls PC.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.
- ❖ Acetamiprid (Assail)
 - An effective insecticide for RAA control.
 - Not the best use of this compound for Michigan growers because it is among the most effective options for summer control of CM and AM.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.
- ❖ Thiacloprid (Calypso)
 - An effective insecticide for RAA control.
 - Not the best use of this compound for Michigan growers because it is among the most effective options for summer control of CM and AM.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.
- ❖ Clothianodin (Clutch)
 - An effective insecticide for RAA control.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.

Non-chemical options

- ❖ Parasitoids generally build-up too late to be effective.

Unregistered chemicals or other control materials

- ❖ Spirotetramat (Movento)

- Small plot trials suggest excellent efficacy.
- A novel mode of action.
- Anticipated 2008 registration.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Fund and conduct research to better identify biology and life cycle of the RAA.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

8. Woolly Apple Aphid (WAA)

- ❖ Injury includes gall formations that increase in size from year to year as the aphids feed. The buildup of galls on young trees affects water and nutrient uptake and reduces tree growth.
- ❖ High populations can result in fruit discoloration from the growth of a black fungus on aphid honeydew excretions.
- ❖ Often becomes a pest after carbamates or pyrethroids are used to control another pest and apparently disrupt natural control of WAA.

Organophosphate insecticides

- ❖ Chlorpyrifos (Lorsban)
 - This was the only OP insecticide available for control of WAA following loss of methyl parathion.
 - Need to find an effective compound or method to control this ever-increasing orchard pest with the loss of Lorsban 50W as a control.
 - No longer registered for control with loss of post-bloom application.

Other insecticides currently registered

- ❖ Endosulfan (Thiodan)
 - Effective, but continued registration under review.
- ❖ Imidacloprid (Provado)
 - Small-plot trials show activity against WAA, but not currently labeled for this use.
- ❖ Thiamethoxam (Actara)
 - Small-plot trials show activity against WAA, but not currently labeled for this use.
- ❖ Acetamiprid (Assail)
 - Small-plot trials show activity against WAA, but not currently labeled for this use.
- ❖ Thiocloprid (Calypso)
 - Small-plot trials show activity against WAA, but not currently labeled for this use.
- ❖ Clothianodin (Clutch)
 - Small-plot trials show activity against WAA, but not currently labeled for this use.

Non-chemical options

- ❖ Resistant rootstocks.
- ❖ Parasitoids.

Unregistered chemicals or other control materials

- ❖ Spirotetramat (Movento)
 - Small plot trials suggest good efficacy.
 - A novel mode of action.
 - Anticipated 2008 registration.

Pest management aids

- ❖ Orchard scouting program.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ More work on natural enemies and their effectiveness.
- ❖ Monitoring programs and economic thresholds.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

9. San Jose Scale (SJS)

- ❖ A driver of OP use, sprays targeted against the immature stage, called crawlers.
- ❖ Scale feeding on woody tissue results in a decline in tree vigor, growth and productivity and if left unchecked, will kill twigs, limbs and eventually the tree.
- ❖ Scale infestations of the fruit causes a distinctive reddish-purple spotting that results in fruit downgrading or culling.

Organophosphate insecticides

- ❖ Chlorpyrifos (Lorsban)
 - Only widely used OP for SJS control.
 - No longer labeled for post bloom applications; this appears to have resulted in a significant increase in this pest.

Other insecticides currently registered

- ❖ Pyriproxifen (Esteem)
 - Provides excellent control of SJS.
 - Will also control RAA if present at time of 1st generation SJS sprays.
- ❖ Oil
 - Effective when pest pressure is low/moderate.
- ❖ Pyrethroid insecticides, Lambda-cyhalothrin (Warrior) and Deltamethrin (Battalion or Decis)
 - Have shown very good to excellent activity on SJS.
 - However, this post-bloom use of pyrethroids may upset mite management programs by destroying beneficial mites and insects.
- ❖ Imidacloprid (Provado)
 - On-farm research is needed.
 - Small plot trials suggest moderate efficacy.
- ❖ Acetamiprid (Assail)
 - Labeled for suppression only, further evaluation needed.
- ❖ Thiacloprid (Calypso)
 - Labeled for suppression only, further evaluation needed.
- ❖ Spintor
 - Moderately effective.
 - Crawler stage only.

Non-chemical options

None identified

Unregistered chemicals or other control materials

- ❖ Thiamethoxam (Actara)
 - Initial testing shows good efficacy, further evaluation needed.
- ❖ Abamectin (Agri-mek)
 - SJS not currently on the label.
 - Small plot trials suggest moderate efficacy.

Pest management aids

- ❖ Black sticky tape is used for monitoring crawlers, determines timing and need for control.
- ❖ Pheromone traps are available for monitoring adult activity.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Screening and development of new compounds.
- ❖ Validation of degree-day model.
- ❖ Potential for biological control.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

10. Tarnished Plant Bug (TPB)

- ❖ Adult feeding results in fruit bud abscission and dimples on fruit.
- ❖ Very difficult to monitor activity of this pest.

Organophosphate insecticides

- ❖ Azinphosmethyl (Guthion)
 - Moderate control and broad spectrum.
- ❖ Phosmet (Imidan)
 - Moderate control and broad spectrum.
- ❖ Chlorpyrifos (Lorsban)
 - Moderate control but no longer labeled for post-bloom use.
- ❖ Diazinon
 - Excellent control and broad spectrum.

- Processor restricts use of this product.

Other insecticides currently registered

- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max).
 - Very effective and economical but use limited due to concerns about disrupting IPM programs.
 - Post-bloom use may upset IPM programs by destroying beneficial mites and insects.
 - If used repeatedly, resistance will occur.
- ❖ Endosulfan (Thiodan)
 - Moderate control.
 - Processor restricts use of this product.
- ❖ Kaolin clay (Surround)
 - Needs more research.
 - Provides some control through feeding deterrence.
- ❖ Azadirachtin (Neemix, Ecozin)
 - Provides moderate control through feeding deterrence.
 - Short residual.
- ❖ Formetanate HCL (Carzol)
 - Good control, but not labeled for use in the eastern US.
- ❖ Indoxacarb (Avaunt)
 - Research trials show activity against TPB, needs more testing.
- ❖ Thiamethoxam (Actara)
 - Moderate lethal effects.
 - Provides control through feeding deterrence.
 - Moderate lethal effects.
 - Needs more research.
- ❖ Thiacloprid (Calypso)
 - Registered for control of mirid bugs, but more research needed.
- ❖ Imidacloprid (Provado)
 - Small-plot trials show activity against TPB, but not currently labeled for this use.
- ❖ Acetamiprid (Assail)
 - Small-plot trials show activity against TPB, but not currently labeled for this use.

Non-chemical options

- ❖ Elimination of broadleaf weeds on the orchard floor will help minimize TPB damage.

- ❖ Time orchard mowing to occur when the nymphs are still in their 3rd to 4th instars, and are therefore incapable of flight.

Unregistered chemicals or other control materials

- ❖ Spirotetramat (Movento)
 - Small plot trials indicate activity against TPB.
 - A novel mode of action.

Pest management aids

- ❖ A reliable method of monitoring is not available.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Pheromone work for monitoring and possible control.
- ❖ Develop and implement a reliable monitoring system.
- ❖ Screening and development of new compounds.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

11. Japanese Beetle (JAB)

- ❖ Adult feeding results in skeletonizing of foliage.
- ❖ Fruit that are mature and previously damaged may be fed upon by adults.

Organophosphate insecticides

- ❖ Phosmet (Imidan)
 - Effective if pest pressure is low/moderate.

Other insecticides currently registered

- ❖ Carbaryl (Sevin)
 - Used when beetle populations are high, but has short residual.
 - Highly toxic to beneficial insects.
- ❖ Pyrethroid insecticides, including Esfenvalerate (Asana), Fenpropathrin (Danitol), Lambda-cyhalothrin (Warrior), Cyfluthrin (Baythroid) and Deltamethrin (Battalion or Decis), and Zeta-cypermethrin (Mustang Max)
 - Least expensive, but use of pyrethroids may upset mite management programs by destroying beneficial mites and insects.
 - Short residual.
- ❖ Kaolin
 - Promising, but more research is needed.
- ❖ Imidacloprid (Provado)
 - Moderate lethal effect.
 - Good feeding deterrence.
- ❖ Azadirachtin (Neemix, Ecozin)
 - Appears to provide some control through repellency.
 - Short lived.
- ❖ Acetamiprid (Assail)
 - Good, but not excellent, insecticide for JB control.
 - Moderate lethal effects; good feeding deterrence.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - Expensive.
- ❖ Thiacloprid (Calypso)
 - Good, but not excellent, insecticide for JB control.
 - Moderate lethal effects; good feeding deterrence.

- One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
- Expensive.
- ❖ Clothianodin (Clutch)
 - Good, but not excellent, insecticide for JB control.
 - Moderate lethal effects; good feeding deterrence.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.
- ❖ Thiamethoxam (Actara)
 - Good, but not excellent, insecticide for JB control.
 - Moderate lethal effects; good feeding deterrence.
 - One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern.
 - 2-3X more expensive than older chemistries.

Non-chemical options

- ❖ None identified.

Unregistered chemicals or other control materials

Pest management aids

- ❖ Traps for population monitoring.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Screening/developing new products.
- ❖ Potential of various attractants and repellents.
- ❖ Effectiveness of kaolin.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.
- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

12. Borers

Dogwood Borer (DWB)

American Plum Borer (APB)

Flatheaded and Roundheaded Borers

- ❖ Borers feed within the trunk of trees, causing loss of vigor and eventual tree death.
- ❖ The incidence of dogwood borer is increasing in all apple production regions.
- ❖ Dogwood borer is a chronic pest on rootstocks that have a high propensity to form burr knots.
- ❖ An estimated 70% of new orchards in Michigan are planted on knot-forming stocks (Mark, M9 & M26).

Organophosphate insecticides

- ❖ Chlorpyrifos (Lorsban)
 - Chlorpyrifos is the **only effective option** for control of this pest complex.
 - Applied in late-June or early July as eggs hatch with a hydraulic gun to the trunk. A second application may be required if pest densities are high.
 - Not applied directly to fruit to control this pest.

Other insecticides currently registered

- ❖ Endosulfan (Thiodan)
 - Not as effective as chlorpyrifos; multiple applications required.
 - Processor restrictions do not allow use.
 - Continued registration in question.
- ❖ Esfenvalerate (Asana)
 - Not used for borer – short residual, thus requires multiple applications.

- Post-bloom use of pyrethroids may upset mite management programs by destroying beneficial mites and insects.
- ❖ Acetamiprid (Assail)
 - Not as effective as chlorpyrifos; multiple applications required.
 - Expensive.

Non-chemical options

- ❖ Mounding soil to cover burr knots below graft union.
 - Effective but leads to other rooting problems.

Unregistered chemicals or other control materials

- ❖ Neonicotinoid insecticides
 - Initial experimental trials indicate that Assail, Calypso and Clutch may be effective as trunk sprays for DWB control, but research is needed before manufacturer will support label changes.

Pest management aids

- ❖ Pheromone traps for monitoring.

Strategies for future control ('To do' list)

Regulatory needs

- ❖ Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. EPA needs to promote parity with imports and not penalize US apple production by forcing the industry to develop tools that do not have MRL's in foreign markets.
- ❖ Improve current EUP process for evaluating new pesticides on farms before registration by developing and implementing a program that will allow researchers to test new chemistries on up to 250 acres prior to full registration.

Research needs

- ❖ Rooststock susceptibility, cultural controls, and role of tree guards.
- ❖ Mating disruption, potential repellents, and white paint mixed with insecticides.
- ❖ Screening/developing new products.

Education needs

- ❖ Expand information on new pest management advances for growers, consultants, and scouts (including use patterns of different classes of chemistries with different modes of activity).
- ❖ Improve delivery of real-time pest management information to the agricultural community.
- ❖ Offer apprenticeship programs for scout training.

- ❖ Help develop and educate a healthy private consultant industry.
- ❖ Inform landowners about issues and laws regulating neglected orchards.
- ❖ Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.

Diseases of Apple

Major Disease Problems

- Apple scab, fire blight and a range of other fruit and foliage disease problems must be controlled annually.
- Adding a second fungicide to an apple scab control program or using later-season applications controls many fungal diseases other than apple scab.
- Weather monitoring and disease forecasting tools play important roles in helping growers make decisions on spray timings and in reducing overuse of bactericides and fungicides.

1. Apple Scab (*Venturia inaequalis*)

Typical Michigan spring weather conditions (cool, wet) are highly favorable to spore release and scab infection. The ubiquitous occurrence and need for chemical control, decreased yield, and reduced fresh market values associated with apple scab make it the most expensive disease in commercial apple production. Most of the standard cultivars used by the industry require annual control programs.

- Leaf infections cause localized lesions or can affect the entire leaf. Leaves may become distorted and cracked. Significant defoliation may occur, which can result in weakened trees that are more susceptible to other diseases, insect pests, and winter freeze damage.
- Infected fruits are scabbed and distorted; they are not fresh-marketable. Pedicel infections may lead to significant fruit drop.
- Chemical control during the primary infection period is essential for successful and economical disease management. This takes place over a period from green tip through June. Maximal spore release usually occurs between pink and petal fall.
- The environmental parameters for the release of spores in spring are well documented, and control decisions based on spore release events are common in the industry.
- Subsequent secondary infections can occur season long by conidia produced on infected tissues; these infections are difficult to control if the primary infection was not controlled.
- The Mills table modified by Jones illustrates the relationship between temperature and time of wetting events and severity of scab infection periods. These easily measured environmental parameters provide critical information to growers on spray timings and the need for fungicide application.

B2 carcinogenic fungicides currently registered:

- ❖ captan (Captan™)

- Broad-spectrum fungicide, no risk for fungicide resistance development.
- Use of this material reduces the number of applications of alternative fungicides at risk due to resistance development.
- Has good protectant and limited eradicant activity.
- Very good retention and redistribution.
- Offers very good control, better as a mixing partner with other fungicide modes of action when used for primary scab control.
- Incompatible with oil sprays.
- Relatively inexpensive material can be used throughout the summer for secondary scab control and has additional activity against some summer diseases.

❖ **metiram EBDC (Polyram)**

❖ **mancozeb EBDC (Dithane, Manzate, Penncozeb)**

❖ **maneb (EBDC) (Maneb)**

- Can be used at full (6 lb/A) rate alone or at half rate tank mixed with many other fungicide modes of action.
- Use of this material reduces the number of applications of alternative fungicides at risk due to resistance development.
- Has good protectant and eradicant activity.
- Very good retention and redistribution.
- Very good scab control material at full rates.
- Excellent material for the control of fruit scab.
- Labeled use only through petal fall is a significant limitation to scab control options.

Other fungicides currently registered:

❖ **Sterol demethylation inhibitors (SI's)**

❖ **myclobutanil** (Nova), **fenarimol** (Rubigan), **fenbuconazole** (Indar), **difenoconazole** (Inspire)

- SI fungicides are systemic, and have protectant and eradicant properties.
- Resistance to SI fungicides in the apple scab fungus is widespread in Michigan and was first reported in 1985.
- SI sprays will yield some level of control, as scab strains with a variety of sensitivity/resistance phenotypes will occur together in orchards. However, resistant strains can buildup such that control failures occur, a situation termed practical field resistance.
- Because of their curative properties, SI fungicides continue to be an important option if growers must apply a spray after the occurrence of an infection period. However, these types of post-infection fungicide applications have the potential to increase fungicide resistance.
- SI fungicides tank-mixed with 1/2 rate EBDC fungicide offer very good scab control.

❖ **Strobilurins**

- **trifloxystrobin** (Flint), **kresoxim-methyl** (Sovran)
- Strobilurins are systemic and their preferred use is as a protectant, but do have eradicant properties.
- Strobilurins offer excellent control of apple scab.
- Strobilurins are single-site fungicides at high risk for fungicide resistance development. Resistance to strobilurins is known in other pathogenic fungi from other cropping systems.
- A maximum of 2-3 sprays per season with no more than two consecutive sprays should be done for resistance management.
- Can arrest spore production if visible scab lesions are present in trees.

❖ **Anilinopyrimidines (AP's)** [**cyprodinil** (Vanguard), **pyrimethanil** (Scala)]

- AP's are systemic and have good eradicant and good protectant properties when mixed with EBDC's
- **AP's** offer very good control, but are a risk for resistance development. Fungicide resistance to AP's has been observed in New York.

- Control is maximized early in the season under colder conditions because AP's break down more quickly under warmer conditions.
 - AP's do not redistribute well so should be combined with an EBDC to maximize effectiveness.
 - Weak at protecting fruit from apple scab infection.
- ❖ **Guanidine [dodine (Syllit)]**
- Resistance to this material is documented in Michigan and the compound is not generally recommended for apple scab control.
 - The percentage of resistant strains drops in orchards over time; however, resistant strains quickly return once dodine is applied again.
 - Samples from orchards should be tested for resistance prior to use.
- ❖ **Thiophanate methyl [thiophanate- methyl (Topsin M)]**
- Resistance to this material is widespread in Michigan and this compound is not generally recommended for apple scab control.
- ❖ **Relatives of EBDC's [carbamate (Ferbam), ziram (Ziram)]**
- Weak protectant fungicides with only 3-5 days of protectant activity.
 - Ferbam is associated with unsightly residues on fruit if applied close to harvest.
 - Ferbam is associated with enlargement of fruit lenticels and russetting of Golden Delicious.
- ❖ **Copper and Sulfur**
- Sulfur compounds have proven ineffective at controlling apple scab.
 - Copper compounds are effective at controlling apple scab; however, the use of copper after green tip results in fruit russetting.
- ❖ **Other pest management aides:**
- Weather monitoring should be used to predict/report apple scab infection periods.
 - Cultural and chemical controls to minimize the level of overwintering primary inoculum are limited in value.

- Protectant sprays are the best way to control apple scab. After infection/post symptom sprays are expensive and should be used only when necessary. Over-reliance may lead to resistance issues in the future.

“To do” list for apple scab:

Regulatory needs:

- Maintain current usage status for EBDC fungicides.
- Increase cost sharing for implementation of IPM technologies (weather and others).

Research needs:

- Screening *Venturia inaequalis* populations for reduced sensitivity to fungicides at risk for the development of resistance (SIs, Strobilurins, Anilinopyrimidines).
- Test new fungicides to find alternatives to carbamate and B2 fungicides and for delaying resistance to available chemistries.
- Test methods to reduce overwintering primary inoculum for standard and organic chemical control strategies.
- Maintain and expand weather monitoring capabilities.

Education needs:

- Emphasize need of proper cultivar selection in orchards with organic or minimal pesticide programs. Resistant cultivars should be promoted.

2. Fire blight (*Erwinia amylovora*)

Fire blight, caused by the bacterium *Erwinia amylovora*, seriously limits apple production in Michigan. Since the 2000 epidemic, crop losses and tree death have exceeded \$50 million to Michigan producers. Compared to the western U.S., Michigan’s humid climate strongly favors this highly weather-driven disease. Fire blight is particularly difficult to manage, and the situation is exacerbated by three major problems: (i) most of the popular apple cultivars grown are either rated as susceptible or highly susceptible to fire blight; (ii) many of the popular dwarfing rootstocks utilized in Michigan are also highly susceptible to fire blight; and (iii) the few chemical control options available are further limited by the development of streptomycin resistance in most areas of Michigan.

- Easily established as cankers in orchards, growth of the fire blight pathogen can increase rapidly to epidemic levels.
- Blossom blight infection reduces yield and enables the bacterium to establish internal infections. Inoculum from blossom infections can cause shoot blight.

- Shoot blight infections and shoot blight initiated following trauma events such as hail are particularly devastating. Shoot infections of young (< 8 yrs old) susceptible apple varieties grown on susceptible rootstocks can ultimately result in tree death and loss of significant percentages of trees per orchard due to rootstock blight.
- Disease can be spread in orchards by wind, rain, hand, machinery, insects such as aphids, leafhoppers, and honeybees, and trauma conditions including hail and blowing sand.
- Rootstock blight is a particularly important problem because this symptom results in tree death. Most apple trees cultivated in Michigan are planted on fire blight susceptible rootstocks. Growers in Michigan have transitioned to highly efficient and productive dwarfing rootstocks at high densities. However, most dwarfing rootstocks available today are highly susceptible to rootstock blight infection.
- Cankers are overwintering sites of the pathogen and can spread and kill branches.

Bactericides currently registered:

❖ Streptomycin (Agrimycin)

- Bactericide – kills the fire blight pathogen upon exposure.
- Used for blossom blight control.
- Most effective blossom blight material by far with normal control exceeding 95% in orchards without streptomycin resistance.
- Only effective eradicator for blossom blight control.
- Use is impacted by streptomycin-resistant strains of the pathogen that occur in the following counties in Michigan: Berrien, Cass, Ionia, Kent, Newaygo, Oceana, Ottawa, Van Buren.
- However, still a widely-used important tool in combination with another mode of action in orchards with mixed levels of streptomycin-resistant and streptomycin-sensitive strains.
- Used for trauma blight control following hail storms.
- OMRI-approved for organic use as an emergency material.

❖ Oxytetracycline (Mycoshield)

- Used as a substitute for streptomycin for blossom blight control in orchards with streptomycin resistance problems.
- Bacteriostatic – inhibits the growth of the fire blight pathogen. Because this material does not kill pathogen cells, it is less effective than streptomycin for control.
- Must be applied prior to infection events and prior to rain events.
- Sprays can be wasted if rainfall predictions are incorrect. Thus, economical use is dependent upon accurate weather forecasts.
- More effective when combined with multiple materials, modes of action.
- Less effective under high disease pressure.
- Ineffective for trauma blight control.

❖ **Copper**

- Bactericide – kills the fire blight pathogen upon exposure.
- Should be applied early up to the half-inch green tip stage for control of pathogen inoculum emerging from cankers.
- Highly efficacious fire blight material, but cannot be used after the half-inch green tip stage because of negative effects on fruit (russetting) and foliage.
- Can be used later in the season in processing blocks or on non-bearing trees.
- Addition of lime to copper solutions may limit fruit russetting.
- Highly important early broad-spectrum material because copper also controls apple scab.
- Available in numerous formulations.

Other materials currently registered:

Biological control agents

❖ **Serenade MAX**

- Biological control consisting of metabolites produced by *Bacillus* sp. with partial effectiveness for blossom blight control.

- If used properly, growers can expect ~ 50% blossom blight control.
- Less effective under high disease pressure.
- Protectant only.
- Ineffective for trauma blight control.

❖ **BlightBan C9-1**

- Bacterial biological control agent (*Pantoea agglomerans* C9-1) with partial effectiveness (~ 10 – 40%) for blossom blight control.
- Living bacterial cells, must be applied early in the bloom period and colonize blossoms prior to the arrival of the *E. amylovora* pathogen. Colonization is variable and weather-dependent and reduced under cool conditions.

❖ **Bloomtime Biological**

- Bacterial biological control agent (*Pantoea agglomerans* E325) with partial effectiveness (~ 10 – 40%) for blossom blight control.
- Living bacterial cells, must be applied early in the bloom period and colonize blossoms prior to the arrival of the *E. amylovora* pathogen. Colonization is variable and weather-dependent and reduced under cool conditions.

Growth Regulator

❖ **Prohexadione calcium (Apogee)**

- Growth inhibitor (controls vegetative growth of the apple tree) that is a highly effective control for shoot blight. Locally systemic.
- Material must be applied at petal fall of the king bloom for maximum effect.
- Does not inhibit bacterial growth.
- No impact on blossom blight.
- Full rate provides maximum shoot blight suppression.

Other pest management aids:

- Pruning to remove cankers is an established practice to reduce inoculum.

- Host resistance is not a significant factor as resistant varieties are not readily available.

PIPELINE – (materials not fully registered or proposed for future use)

Alternate antibiotics

❖ **Gentamicin (Agris-Gent)**

- Similar class of antibiotic as streptomycin has excellent efficacy for blossom blight control and for control of streptomycin-resistant fire blight bacteria. A Section 18 specific exemption for the use of gentamicin was obtained in 2007 for use in three counties (Berrien, Kent, Van Buren) impacted by streptomycin resistance.

❖ **Kasugamycin (Kasumin)**

- Similar class of antibiotic as streptomycin has excellent efficacy for blossom blight control and for control of streptomycin-resistant fire blight bacteria.
- Has no uses in human medicine and is a desirable and effective alternative to streptomycin.

“To do” list for fire blight:

Regulatory needs:

- Accelerate the registration of new antibiotics. The availability of multiple modes of actions will enable growers to control streptomycin-resistant strains of the fire blight pathogen and will protect the other antibiotics from resistance development.

Research needs:

- Test new antibiotics and integrate with growth regulators to maximize control during the season.
- Routine surveys to assess the movement of streptomycin-resistant strains into new orchards.
- Assessment of the development of antibiotic resistance in non-target bacteria in orchards where new antibiotic materials (gentamicin and kasugamycin) are used.
- Mix Serenade MAX with additional materials such as phosphorous acid products and determine if the combinations will increase efficacy.
- Assess blossom colonization and spread of bacterial biological control agents under Michigan conditions. Understanding the colonization potential of bacterial biological

- Maintain and expand weather monitoring capabilities

Education needs:

- Emphasize proper cultivar/rootstock selection to minimize fireblight epidemics.
- Biology, monitoring, resistance management and use of predictive models.

Other Disease Problems of Apple

The importance of the following diseases varies. In individual orchard/weather/cultivar combinations however, they can represent severe threats to apple production and marketability. Most require control measures in addition to those for apple scab and fire blight.

3. Powdery Mildew (*Podosphaera leucotricha*)

Powdery mildew occurs in all apple-growing regions and can cause extensive infection, especially in dry years following mild winters. Young expanding tissues are most sensitive and annual control programs are required from pink until the terminal buds have set and new leaves are no longer produced. Powdery mildew can be especially damaging in nurseries or during orchard establishment since non-bearing trees may produce susceptible tissues late into the summer. Infections of blossoms can lead to reduced fruit set, small fruit, or russetting which greatly reduces fresh market value. Differences in varietal sensitivity are known.

B2 carcinogenic fungicides currently registered:

- ❖ None of the B2 carcinogenic fungicides are active against powdery mildew.

Other fungicides currently registered:

- ❖ **Sterol demethylation inhibitors (SI's)** [**myclobutanil** (Nova), **fenarimol** (Rubigan), **fenbuconazole** (Indar), **difenoconazole** (Inspire)]
 - Best fungicide class available for powdery mildew control.
 - Disease control program should be initiated at the pink stage and continue through 2nd cover.
 - SI's should be tank-mixed with EBDC fungicides for control of both powdery mildew and apple scab.
- ❖ **Strobilurins**

- **trifloxystrobin** (Flint), **kresoxim-methyl** (Sovran)
- Highly effective powdery mildew material; however, there is a risk of fungicide resistance development.
- Disease control program should be initiated at the pink stage and continue through 2nd cover.
- ❖ **Strobilurin + Boscalid**
 - pyraclostrobin and boscalid (Pristine)
 - Highly effective powdery mildew material; however, there is a long-term risk of fungicide resistance development.
- ❖ **Anilinopyrimidines (AP's)**
 - cyprodinil (Vanguard), pyrimethanil (Scala)
 - AP's are not effective against powdery mildew.
- ❖ **Topsin M and Bayleton**
- ❖ **Sulfur**

Other pest management aides:

- If oils are used for mite control there may be a risk of phytotoxicity when Sulfur is used.
- Cultural practices to promote air circulation may aid control by lowering orchard humidity.
- Resistant varieties.

“To do” list for powdery mildew:

Regulatory needs:

- Accelerate the registration of new antibiotics. The availability of multiple modes of actions will enable growers to control streptomycin-resistant strains of the fire blight pathogen and will protect the other antibiotics from resistance development.

Research needs:

- Continue to develop broad-spectrum fungicides.

Education needs:

- Emphasize need of proper cultivar selection in sites prone to powdery mildew infection.
- Emphasize need for constant coverage from before bloom until the growth of new tissues has stopped, regardless of insufficient leaf wetness periods to support apple scab infection.

4. Phytophthora Crown, Collar, and Root Rot (*Phytophthora megasperma*, *P. cryptogea*, *P. cambivora*, *P. syringae*, *P. cactorum*, and other *Phytophthora* spp.)

These pathogens can cause the decline and loss of trees grown in sites with poor soil drainage.

Other fungicides currently registered:

- ❖ mefenoxam (Ridomil Gold)
- ❖ fosetyl-Al (Aliette)

Other pest management aides:

- *Phytophthora* spp. are probably present in most soils and may be present in nursery trees; proper site selection is very important.
- Avoid planting in soils with poor soil drainage to help manage this disease.
- Tiling of marginal sites or planting on berms to increase drainage.
- Use rootstocks with resistance to *Phytophthora* spp. on marginal sites.

PIPELINE: none currently known

“To do” list for Phytophthora crown and root rots:**Regulatory needs:**

- Maintain currently available materials due to limited number of alternatives.

Research needs:

- Continue screening *Malus* rootstocks for resistance to *Phytophthora* spp.
- Test efficacy of materials used for control of other *Phytophthora* species.

Education needs:

- Emphasize need of proper site selection or site preparation.

- Biology and control methods.

5. Black Rot, Frogeye Leafspot, and Canker (*Botryosphaeria obtusa*)

This endemic fungus can affect apple trees in multiple ways. Branch cankers cause dieback and loss of bearing surface. The cankers typically occur on stressed or weakened trees; infection of winter damaged limbs or branches killed by fire blight is common. Fruit infections can cause a loss of product and marketability. Leafspots reduce photosynthetic efficiency and may cause defoliation which can result in reduced fruit quality and yield.

B2 carcinogenic fungicides currently registered:

- ❖ **captan** (Captan) - highly effective black rot control material, needed for resistance management.
- ❖ **Other fungicides currently registered:**
- ❖ **myclobutanil** (Nova) – not effective against black rot.
- ❖ **thiophanate- methyl** (Topsin M) – effective black rot material, should be tank-mixed with Captan for resistance management.
- ❖ **pyraclostrobin and boscalid** (Pristine) – effective black rot material, useful for late season application targeting fruit infection.
- ❖ **kresoxim-methyl** (Sovran) – effective black rot material, useful for late season application targeting fruit infection.

Other pest management aides:

- Sanitation is generally advised for control. Prune out infected limbs and cull infected fruit. Some studies suggest however, no apparent linkage between incidence of the canker diseases and incidence of the fruit rot diseases.
- Fruit rot (Black rot) and leafspot (Frogeye) stages are typically controlled by fungicides used for apple scab control but cankers are not controlled chemically.
- Cultural practices to maintain optimum tree vigor should be followed.
- EBDCs and SI fungicides have limited activity against *Botryosphaeria* species.

“To do” list for *Botryosphaeria obtusa* diseases:

Regulatory needs:

- None

Research needs:

- Examine the connection between levels of cankers in the trees or in adjacent brush piles to the occurrence of fruit rot (Black rot).
- Screen fungicides for fruit rot control efficacy and spray timings for effective fruit rot control.

Education needs:

- Emphasize need of proper pruning, sanitation, and cultural practices to insure vigor for the management of diseases caused by *B. obtusa*.

6. Flyspeck (*Schizothyrium pomi*) and Sooty Blotch (Complex of *Gloeodes pomigena*, *Peltaster fructicola*, *Leptodontium elatius*, and *Geastrumia polystigmatis*)

These fungi cause a conspicuous discoloration of the cuticle which can reduce market value and cause economic loss. These summer diseases are normally controlled by apple scab fungicide treatments but can become problematic, especially on apple scab resistant cultivars where growers have substantially reduced the number of fungicide applications and in organic orchards. Under warm, wet conditions, up to 25% of fruit may be infected.

B2 carcinogenic fungicides currently registered:

- ❖ **captan** (Captan) – provides good control of flyspeck/sooty blotch; resistance management tool as well.

Other fungicides currently registered:

- ❖ **ziram** (Ziram) – only fair control of flyspeck/sooty blotch.
- ❖ **trifloxystrobin** (Flint) – good to very good control of flyspeck/sooty blotch; should be tank-mixed with Captan for resistance management.
- ❖ **kresoxim-methyl** (Sovran) – good to very good control of flyspeck/sooty blotch; should be tank-mixed with Captan for resistance management.
- ❖ **thiophanate-methyl** (Topsin M) – very good control of flyspeck/sooty blotch; should be tank-mixed with Captan for resistance management.
- ❖ **pyraclostrobin and boscalid** (Pristine) – good to very good control of flyspeck/sooty blotch; should be tank-mixed with Captan for resistance management.
- ❖ **fenarimol** (Rubigan) -- only fair control of flyspeck/sooty blotch.

Other pest management aides:

- Remove brambles (reservoir hosts) from areas adjacent to orchard blocks.
- Prune to open up the canopy to facilitate drying of fruit surfaces.
- Use of summer disease models for proper control timing.

“To do” list for Flyspeck and Sooty Blotch.

Regulatory needs:

- EBDC's are highly effective but not currently labeled.

Research needs:

- Examine impact of reduced fungicide use, as on apple scab resistant cultivars or in organic orchards, on disease incidence.
- Control options for organic growers.

Education needs:

- Emphasize detection and need of proper pruning and reservoir host management.
- Promote use of newly developed summer disease models.

7. Other Canker Fungi: Leucostoma canker (*Leucostoma cincta*); White Rot Canker (*Botryosphaeria dothidia*); Diplodia canker (*Diplodia mutila*); Coral spot (*Nectria cinnabarina*); and Anthracnose canker (*Cryptosporiopsis curvispora*).

These canker diseases can be locally important and cause losses to bearing twigs and branches. These are indigenous fungi which opportunistically infect apple trees under certain conditions, for example: reduced vigor, cold injury, improper pruning, or in particular fungus/cultivar combinations. There are no chemical controls for these cankers.

B2 carcinogenic fungicides currently registered:

- ❖ none

Other fungicides currently registered:

- ❖ none

Other pest management aides:

- Sanitation, pruning out infected branches and disposing of the trimmings is important. These fungi may survive in brush piles.
- Cultural practices to improve vigor and proper pruning are essential.
- Maintain healthy tree.

“To do” list for Canker diseases cause by miscellaneous fungi.

Regulatory needs:

- None

Research needs:

- Prevalence, distribution, management, and remediation studies are required.

Education needs:

- Emphasize cultural practices to minimize wounding, improve vigor, and promote wound closure.

8. Other Fruit Rots: *Alternaria* rot (*Alternaria* spp.); Bull’s-eye Rot (*Cryptosporiopsis curvispora*); Bitter Rot (*Colletotrichum* spp.); and White Rot (*Botryosphaeria dothidea*).

These summer fruit infections can cause a loss of product and marketability in the field and post-harvest. They are normally controlled by apple scab fungicide treatments but can become locally problematic under certain environmental conditions and in particular fungus/cultivar combinations.

B2 carcinogenic fungicides currently registered:

- ❖ **captan** (Captan) – best material for other summer fruit rots because of broad-spectrum mode of action.

Other fungicides currently registered:

- ❖ **ziram** (Ziram) – only fair control of other summer fruit rots.
- ❖ **trifloxystrobin** (Flint) -- good to very good control of other summer fruit rots; should be tank-mixed with Captan for resistance management.

- ❖ **kresoxim-methyl** (Sovran) -- good to very good control of other summer fruit rots; should be tank-mixed with Captan for resistance management.
- ❖ **thiophanate-methyl** (Topsin M) -- good to very good control of other summer fruit rots; should be tank-mixed with Captan for resistance management.
- ❖ **pyraclostrobin and boscalid** (Pristine) -- good to very good control of other summer fruit rots; should be tank-mixed with Captan for resistance management.

Other pest management aides:

- Pruning and sanitation is often suggested because many of these fungi also cause cankers. Some studies suggest however no apparent linkage between incidence of the canker diseases and incidence of the fruit rot diseases.
- EBDCs and SI fungicides have limited activity against *Botryosphaeria* species.

“To do” list for Fungal Fruit Rots.

Regulatory needs:

- None

Research needs:

- Prevalence, distribution, management, and fungicide efficacy studies are required.

Education needs:

- Emphasize disease detection and maintenance of proper summer disease control programs.

9. Blue Mold (*Penicillium expansum* and other *Penicillium* spp.)

Blue mold is a common post-harvest disease on apples. *Penicillium* spp. typically infects through fruit wounds; punctures, bruises, and limb rubs. It is an economic concern for fresh-fruit and processing since some strains produce mycotoxins that affect apple juice production. Limited fungicide options make this disease susceptible to resistance development, and therefore a more serious disease problem.

B2 carcinogenic fungicides currently registered:

- ❖ **captan** (Captan) – partial effectiveness in blue mold control.

Other fungicides currently registered:

- ❖ **thiabendazol** (Merteck) – used as a postharvest drench; however, resistance has been reported in some locations.
- ❖ **pyrimethanil** (Penbotec) – used postharvest as a drench, dip, or line spray for blue mold control; also can be effective in controlling blue mold originating from wound infections.
- ❖ **pyraclostrobin and boscalid** (Pristine) -- use immediately prior to harvest to control blue mold in blocks where this disease has been a problem.

Other pest management aides:

- Minimize wounding and compression injury during harvest and post-harvest handling.
- *Penicillium* spores are often found in fungicide-drench solutions, flume water, dump-tank water, and on the walls of storage rooms.
- Thiabendazole-resistant isolates of *P. expansum* have been noted as being common in packinghouses.
- Sanitation measures by growers, storage operators, and packinghouses are important, but not a substitute for chemical control.

“To do” list for Blue Mold.

Regulatory needs:

- None

Research needs:

- Prevalence, distribution, management, and fungicide efficacy studies are required.
- Potential food safety issues.

Education needs:

- Emphasize sanitation and proper harvesting, handling, and storage protocols.
- Raise awareness of industry of potential mycotoxin problems.

IPM for Weeds

Weed management is critical to tree growth, and is important for pollination, control of wildlife, and management of insect, mite and disease pests. Understory and drive row plant growth is also important habitat for natural enemy and pollinator populations.

- Weeds compete with newly planted tree and mature bearing trees for nutrients and water.
- Chemical weed management conserves soil moisture.
- Weeds host pests and beneficials, including insects, nematodes, and viruses.
- Weeds when flowering compete for pollinating bees in the spring.
- Weeds provide cover for undesirable animals (rodents).
- Weeds adversely affect apple quality and yield and impede harvest.
- Weed seedheads can clog machinery radiators.
- Growers routinely mow the centers (between rows) of orchard floors periodically to maintain a sod cover. Mowing activity provides some control of orchard weeds and reduces some pest populations. Herbicides are applied in strips under tree rows, to the drip line (canopy width), providing weed control.
- Repeated use of the same or similar weed control methods results in weed shifts to species that tolerate the control method and new species that thrive in weed controlled areas.
- A combination of weed control practices, herbicide applications, rotation of practices and materials are utilized to prevent weed shifts.
- Sod middles reduce and prevent erosion, improve traffic conditions especially when wet, increase water infiltration and drainage, and act as a major carbon reservoir in orchards.
- Growers match herbicide rates to soil types. Lower per acre rates are applied on lighter soils (sandy or gravelly) or soils with lower cation exchange capacities.

Pest Management Aids (Not stand alone)

Researchers and growers are experimenting with different types of orchard floor management, such as mulching, composting, and mixed species groundcovers as ways to reduce reliance on herbicides while reducing erosion and maintaining production. These options are generally more expensive and labor intensive to implement. Long-term increases in nutrient and water availability to the tree can be achieved by certain ground cover management practices. These practices can have both positive and negative effects on wildlife management. While mulch tends to have a positive impact on growth and yield, soil moisture and soil quality, mites have been a problem.

- No effective biological control.

- Mechanical weed control is a viable option for some growers wanting to reduce herbicide use (i.e. organic producers)

Herbicides for weed control on new plantings and/or established orchards.

Pre-emergence broad leaves and grasses

❖ Simazine (Princep)

- Not used on first year plantings.
- Applied as a pre-emergent in late fall or early spring to control many herbaceous broadleaf weeds and grasses.
- Exhibits reduced leaching characteristics.
- A triazine herbicide prone to soil residue carryover from year to year.
- Will not control established vegetation.
- Often combined in a tank mix with one or more other herbicides to obtain a broader spectrum of control.
- Agitation of the spray mixture during application is required to maintain a uniform mixture.

❖ Oryzalin (Surflan)

- Requires significant moisture for incorporation.
- Pre-emergent in early spring to control annual and late-season grasses and some broadleaf weeds.
- Established vegetation will not be controlled.
- napropamide (Devrinol)
- Requires significant moisture for incorporation.
- Control of several grass and broadleaf weeds.

❖ Norflurazon (Solicam)

- High label rates cause distinct leaf symptoms of veins turn white or pinkish white.
- Persistent in the soil at high label rates may not result in symptoms until late in the season or the following year
- REI=12 hours, PHI=60 days.

❖ Pendimethalin (Prowl)

- Control of broadleaf weeds and annual grass.

- Rate is dependent on soil type.

❖ **Flumioxazin (Chateau)**

- Contact and residual herbicide that controls both grasses and broadleaf.
- Effective as a pre-emergence.
- Expensive.
- Most effective when applied while the emerged weeds are very small.
- REI is 12 hours, PHI is 60 days.

❖ **Isoxaben (Gallery)**

- Selective, pre-emergent control of broadleaf weeds in non-bearing orchards.
- Apply in late fall or early spring.

❖ **Oxyfluorfen (Goal)**

- Apply during dormant only.

❖ **Dichlobenil (Casoron, Norasac)**

- Granular form only (requires special equipment; therefore rarely used).
- Late fall only.
- Applied as a pre-emergent to inhibit seed germination of both grasses and broadleaf weeds.
- A good rain is needed following application to activate the material.
- Expensive, 30 day PHI.

❖ **Pronamide (Kerb)**

- Late fall only.
- Expensive, not widely used.
- A selective herbicide that controls certain broadleaf plants and grasses, particularly quackgrass.
- A soil-applied herbicide that has little foliar activity and requires rain following application so root uptake can occur.
- Best results when applied in late fall before soil freeze-up when air temperatures do not exceed 55 degrees F.
- More effective on soils with low levels of organic matter.

❖ **Diuron (Karmex, Direx)**

- Widely used.
- Apply one application in the spring as a pre-emergence.
- Used with post-emergence herbicides.

❖ **Rimsulfuron (Matrix)**

- Pre-emergence on grasses and broadleaves.
- Good on young post-emergence broadleaves.
- REI= 4 hours, PHI= 7 days.

❖ **Terbacil (Sinbar)**

- Good on annual grasses and annual broadleaves.
- Reduced rates used on sandy soils.
- REI=12 hours, PHI=60 days.

Post-emergence annuals and perennials

❖ **Glyphosate**

- Widely used, except in young plantings.
- Additives must be mixed with glyphosate for effectiveness.
- Applied in spring, summer or fall for control of numerous grasses, broadleaf weeds and woody species .
- Drift can injure established trees .
- There is no soil residual.
- REI=12 hours, PHI=1 day.

❖ **Paraquat (Gramoxone)**

- Widely used.
- Resistance unlikely.
- Annuals only.

❖ **2,4-D Amine (Weedar, HiDep)**

- Broadleaf plants.
- Not used first year.
- Not used at bloom (toxic to pollinators).
- Will volatilize under elevated temperatures (<68).
- Used to remove broadleaved weeds (particularly dandelion).

- 2,4-D is available under many trade names and commercial formulations.
- REI=48 hours, PHI=14 days.

❖ **Sulfosate (Touchdown)**

- This compound is similar to glyphosate in mode of action and activity.
- REI=12 hours.

❖ **Glufosinate (Rely)**

- A non-selective, contact herbicide .
- Excellent control of suckers on established trees.
- REI=12 hours, PHI=14 days.

❖ **Carfentrazone (Aim)**

- Post-emergence for annual broadleaves.
- Will control suckers.
- REI=12 hours, PHI =3 days.

❖ **Fluazifop-P (Fusilade)**

- Post-emergent to control actively growing grasses.
- Not widely used, expensive.

❖ **Sethoxydim (Poast)**

- Control a wide variety of annual and perennial grasses.
- Does not control sedges or broadleaf weeds.

❖ **Copyralid (Stinger)**

- Very active on difficult to control grasses.
- REI=12 hours, PHI=30 days.

❖ **Clethodim (Select)**

- A post-emergence selective (grass-only) herbicide, similar to Poast, Fusilade.
- Somewhat effective on quackgrass,
- For NON-BEARING apples.
- Used for spot treatment.
- REI= 24 hours.

❖ Sandea

- Very expensive.
- Controls broadleaves.

Research needs:

- Continued evaluation of alternative management systems.
- More information is needed on the interaction of orchard floor management with pollinators, beneficial organisms, tree nutrition, soil organisms, pests, wildlife, etc.
- Role of ‘weeds’ in orchard ecology.
- Establish more reliable weed damage thresholds.
- Test new herbicides as they become available.
- Methods to identify resistance.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

- As products and/or weed management strategies become available, educate users.

Wildlife Control

Wildlife control is an especially important concern for Michigan apple producers due to high deer populations and the presence of woodlots in close proximity to orchards. Wildlife includes deer, mice, raccoons, voles, rabbits, birds, and woodchucks. These animals damage and kill fruit trees and consume and/or damage apples. Deer are particularly damaging to young orchards, resulting in extensive production loss. Where feasible, biological controls are encouraged for wildlife control.

White-tail deer

Cause considerable damage to orchards. Will feed on buds, shoots and fruit throughout the growing season. Damage is caused by deer rubs on trees.

Repellents

❖ **Rotten eggs, capsaicin (hot sauce), dried blood meal, thiram, Hinder, garlic, human hair, soap, and fabric softener sheets**

❖ **Deer fencing (10' high)**

- Alternative method.
- Expensive but effective.

❖ **Dogs (w/invisible fence)**

- Alternative method.
- Expensive but effective.
- High maintenance.

❖ **Summer kill permits**

- State permit required.
- Highly effective.

❖ **Thiram**

- Not very effective, not widely used.

Voles and mice

Voles and mice will cause serious damage to trees, even death by extensive feeding on the roots and trunk of trees. Often the most serious damage occurs on the borders of orchards near wild areas.

Repellants

❖ **Tree guards**

- Barriers to prevent girdling, but can serve as pest habitat (i.e. codling moth).

Toxicants

❖ **Zinc-phosphide (various baits)**

- Acute toxicant, single feeding provide lethal dose.
- Applied by broadcast, spot treatments and bait station.
- Highly toxic to all birds and mammals.

❖ **Diphacinone (Ramik)**

- Broadcast or bait station.
- Continuous feed anti-coagulant, need multiple feeding to be lethal.
- Highly toxic to all birds and mammals.

❖ **Chlorophacinone (Rozol)**

- Hand bait pellets and sprayable.
- Highly toxic to all birds and mammals.

Nematodes

Nematode damage can be minor to moderate in young apple orchards. Damage is likely to be seen in the first few years following planting. Root-lesion nematodes penetrate into roots, tunneling and feeding in the root tissues causing permanent damage to the tree. Nematodes can be controlled before or after planting through chemical controls and alternative ground floor management.

Nematicides

❖ Fenamiphos (Nemacur 3)

- Workhorse nematicide used mostly where known populations exist.
- No longer produced, may be applied until inventory depleted.

❖ Oxamyl (Vydate)

- Widely used nematicide.

❖ Dichloropropene (Telone, fumigants)

- Used pre-plant treatment.

❖ Metam sodium (various fumigants)

- Used pre-plant where nematodes exist.

Plant Growth Regulators (PGR), Post-Harvest Treatments, Herbicides, and Nematicides

Growth Regulators

Thinning and other horticultural practices are very important to the Michigan apple industry. Growth regulators are important pest management factors because they influence fruit load, and plant physiology, which in turn influence pest and beneficial populations. Some growth regulators also act as insecticides (carbaryl), but its primary use to the industry is as a growth regulator, not an insecticide. Apples are very prone to producing a crop every other year. To reduce this biennial bearing habit, chemical thinning is a critical management practice. Growers rely on a variety of products, however Carbaryl (Sevin) is an especially important thinning tool. This carbamate is used extensively at low rates in combination with other materials (Naphthaleneacetic acid (NAA) or Benzyladenine (BA) from bloom until 2-3 weeks post-bloom.). In addition, Prohexadione calcium (Apogee) is an important growth regulator that also suppresses disease (fireblight), and some insect pests (leafrollers) by inhibiting shoot growth. Chemical thinning is a critical practice because the alternative, hand thinning, is cost prohibitive, not as effective in ensuring return bloom, and complicated by REI's for other pesticides.

Apple Plant Growth Regulator (PGR)

❖ Naphthaleneacetic acid (NAA)

- Most important thinner, along with carbaryl.
- Used in combination with other thinners on 95% of blocks requiring thinning.
- Not compatible with Benzyladenine (BA).
- Phytotoxic on some varieties (Red Delicious, Fuji).
- Used to increase return bloom (reduce biennial bearing).
- Used to control water sprouts and vegetative re-growth from pruning cuts.

❖ Carbaryl (Sevin)

- Most important thinner, along with NAA.
- Used in combination with other thinners on 95% of blocks requiring thinning.
- Used at 1/8 to 1/4 full rate per acre.
- Has insecticidal activity at full rates/acre.

❖ Benzyladenine (BA, MaxCel, Exilis)

- Important thinner.
- Used alone or in combination with Carbaryl (Sevin).
- Used on small fruited varieties and Naphthaleneacetic acid (NAA) sensitive varieties.

- Not compatible with Naphthaleneacetic acid (NAA).
- Dose dependent, (higher rates thin more).
- REI = 4 days.

❖ **Naphthaleneacetimide (NAD)**

- Minor thinner.
- Important on a few varieties.
- Used on 5% of orchards.
- REI = 48 hours.

❖ **Gibberellins A4+7, Benzyladenine (Promalin, Perlan)**

- Used to promote size and shape of fruit.
- Used on only certain varieties, mostly Red Delicious.
- Expensive, Used on <5% of acreage.
- Used to promote branching on young trees.
- Not compatible with Naphthaleneacetic acid (NAA) on Red Delicious.
- REI = 4 hours.

❖ **Gibberellins A₄₊₇ (Provide, Novagib)**

- Used to reduce russet on fresh Golden Delicious.
- Used to reduce return bloom (very minor).
- Not used on processing varieties.
- REI = 12 hours.

❖ **Prohexadione calcium (Apogee)**

- Used to suppress vegetative growth on apple.
- Suppresses shoot growth, thereby reducing incidence of Fire Blight infections and insect pests.
- Phytotoxic to some varieties (Empire, Stayman Winesap).
- REI = 12 hours, PHI = 45 days.

❖ **Aminoethoxyvinylglycine (ReTain)**

- Used pre-harvest to delay maturity.
- Used pre-harvest to stop drop of apples.

- Expensive, but use increasing in industry at reduced rates on some varieties
- Improves shelf life of fruit
- REI=12 hours, PHI=21 days

❖ **Ethephon (Ethrel, Chepha)**

- Used to ripen fruit, improve red color.
- Used to promote return bloom.
- Used to thin fruit but is somewhat unpredictable.
- Provides some vegetative shoot control.
- REI = 48 hours; PHI =7 days.

❖ **1-methylcyclopropene (Harvista)**

- Pre-harvest sprayable 1-methylcyclopropene.
- Used to reduce pre-harvest fruit drop.
- Delays the ripening process of fruit.
- Delays fruit softening in storage.
- New PGR expected to be labeled in 2008.

Post-Harvest

Some apple varieties do not require post-harvest treatments before storage and are not treated at all with post-harvest drenches. Other varieties are very prone to post-harvest disorders such as scald, rot, CO² injury, breakdown, lenticel spot and bitterpit. These varieties when stored for long term must be treated with post-harvest drenches to limit decay. Smart Fresh is a new treatment that benefits most varieties stored long term.

❖ **1-methylcyclopropene (SmartFresh)**

- Delays the ripening process of fruit.
- Controls storage physiological disorders.
- Applied as a gas after harvest in storage rooms.
- Control Storage Scald on some varieties.
- Expensive.

❖ **Diphenlamine (No Scald DPA)**

- Applied as a post-harvest drench; being investigated as a fog treatment in storage.
- Controls Storage Scald on some varieties.
- Controls CO² injury on Empire.
- Requires the addition of post-harvest fungicide to control rot.

❖ **Thiabendazole (Mertec)**

- Broad-spectrum fungicide applied as a post-harvest drench.
- Controls various post-harvest rots.
- Included when apples are treated with other post-harvest drenches.
- Blue mold pathogen has developed resistance; results in reduced use.

❖ **Pyrimethanil (Penbotec)**

Applied as a post-harvest drench.

New post-harvest fungicide for control of rot.

Used extensively as replacement of benomyl fungicides.

Used in combination with Captan.

Very expensive.

❖ **Captan (Captan, Captec)**

- Applied as a post-harvest drench, labeled as in-season fungicide.
- Older post-harvest fungicide, used where resistance is problem.
- Used in combination with pyrimethanil (Penbotec).
- Not allowed on apples exported to Canada.
- REI = 24 hours, PHI = 1 day.

*Footnote: Calcium is included as a post-harvest drench on some varieties that are prone to post-harvest disorders. These include Bitterpit, Internal Breakdown, Lenticel Spot, fruit softening and other problems.

Timeline of Worker Activities in Apple Orchards

Early Season Activities (no pesticides applied during this time period):

- ❖ *January/February (Dormant):* Tree pruning & trimming, equipment repair.
- ❖ *March:* Tree pruning & trimming, equipment repair, push & chop brush, dormant scouting (European Red Mite, scales and fireblight cankers), deploy deer repellent and fencing.
 - Average time in orchard chopping/pushing brush = 2 hr/10 ac.

In-Season Activities (Pesticides applied & residues present during this time period)

- ❖ *April through September:*
 - There are no aerial pesticide applications in Michigan Apple production.
 - *ca.* 150 day pesticide application period from middle April to September; decisions are made on a block by block basis (by variety and pest pressure).
 - 98% of apples are harvested in September and October.
 - *Ca.* 99% of insecticides/fungicides/bactericides applied by Michigan Apple industry is from closed cab sprayers with pesticide rated ventilation filtration systems.
 - *Ca.* 50% of Michigan Apple growers apply insecticides/fungicides/bactericides using alternate row applications.
 - An estimated average of 8 to 12 insecticide/fungicide/bactericide applications are made per block/year.
 - *Ca.* 20% of MI apple acreage receives a hand application of pheromone mating disruption from mid-April to mid-May; often associated with reduced insecticide use.
 - Orchard mowing on average done 3X/yr during 150-day residue window; average mowing time = 2 hours/10 ac.
 - In orchard professional monitoring services average 15 minutes/10 ac scouting for insect and disease pests, weekly, up to 16X season; scouts regularly communicate with growers to observe REI restrictions.
 - Summer pruning, *ca.* 5% of MI acreage is summer pruned. (declining practice)
 - Herbicide applications performed on average 2X per year during 150 day residue window; average application time = 1.5 hrs/10 ac.

- *Ca.* 15% of Michigan Apple industry uses supplemental irrigation; average time spent checking irrigation lines = 1 hr/10 ac 2X during residue window.
 - 100% of Apple harvest is performed by hand, average of 1 worker/5 ac, 1 inspector/30 workers, 2 lift truck operators/30 workers.
- ❖ *April & May:* weekly insect and disease scouting begins, bees deployed for pollination, frost protection as needed (wind machines), mowing of drive rows, planting and installing irrigation and trellis.
- *Potential Spray Applications*
 1. Fungicides for Apple Scab, Fire Blight, Powdery Mildew, applied as needed depending on rain events.
 2. Insecticides for Oblique Banded Leafroller, European Red Mite, Spotted Tentiform Leafminer, Rosy Aphid, Plum Curculio, White Apple Leafhopper, Codling Moth, Green Aphid.
 3. Herbicides if weather conditions favorable for weed development
 4. Plant growth regulators at Bloom and during thinning period.
- ❖ *June through August:* weekly insect and disease scouting continues, mowing of drive rows, tree training check irrigation lines, hand thinning, Spray applications are discontinued by or before appropriate PHI, with 99% discontinued by early September.
- *Potential Spray Applications*
 1. Fungicides for Apple Scab, Fire Blight, Powdery Mildew, Summer diseases.
 2. Insecticides for Codling Moth, Oblique Banded Leafroller, Oriental Fruit Moth, Apple Maggot, Green Aphid, Leafhoppers, Japanese Beetle as needed.
 3. Herbicides (as-needed spot sprays).
 4. Growth Regulators vegetative control and return bloom.
- ❖ *August through October:* weekly insect and disease scouting continues, mowing of drive rows, preparing for harvest, move in bins. Hand harvest fruit at appropriate maturity.
- *Potential Spray Applications*
 1. Spray applications are discontinued by or before appropriate PHI and 99% discontinued in early September. Late spray applications only applied in late harvested varieties where a problem pest population has been identified.
- ❖ *Nov/Dec:* Manure applications and very limited herbicide applications, tree pruning & trimming, equipment repair.

Table 2. Major Material Applications and Activities for Apple

Major Material Applications and Activities for Apple (not including insecticides, & miticides)																																
Month	Apr				May				Jun				Jul				Aug				Sep				Oct				Nov			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Full Bloom																																
Apple Scab (Primary)																																
Apple Scab (Secondary)																																
Fire Blight																																
Powdery Mildew																																
Summer Diseases																																
Pre-Harvest Rot																																
Apogee																																
Chemical Thinning																																
Russet Control																																
Return Bloom																																
ReTrain																																
Early Apple Harvest																																
Fall Apple Harvest																																
Late Apple Harvest																																

**This chart reflects statewide use. Actual period of application by any individual grower will be reduced. Period of application is extended to account earliest use in southern production regions to the latest use in northern regions.

Table 3. Important insect pests in Michigan apple

Pests	Type of damage
Codling moth	Larvae tunnel into apples
Oriental fruit moth	Larvae feed inside apples
Leafrollers: obliquebanded, redbanded, variegated, tufted apple bud moth, and eyespotted bud moth	Feed on leaves and fruit, damaged fruit are culled
Plum curculio	Distortion of fruit and fruit loss; larva may remain in fruit at harvest
Apple maggot	Rejection of crop due to maggots in fruit at harvest, zero tolerance
Green fruitworm	Feeding on young fruit
Rosy apple aphid	Twisting of leaves, stunted apple and shoot growth
Woolly apple aphid	Feeding causes gall formation, reduces tree growth and vigor
San Jose Scale	Weakening of trees (reduced vigor), Distinctive red marks on fruit
Tarnished plant bug	Weakening of trees (reduced vigor), Distinctive red marks on fruit
Japanese beetles	Adults skeletonize leaf tissue
Dogwood and other borers	Girdling of branches and trunk, killing of branches and trees
European Red, Two-Spotted Spider, and Apple Rust mites**	Bronzing or browning of leaves, defoliation, branch die back; become key pests under certain climactic and management conditions
White apple and potato leafhoppers	Feeding removes leaf chlorophyll affecting fruit quality and bud formation; most problematic in dry years
Spotted tentiform leafminer	Larvae mine leaves; can cause stunting of fruit growth and reduced fruit set the following season
Campylomma (mullein bug)	Feeds on flower parts and developing fruit

**where present can cause severe injury over time without control

Table 4. Efficacy Ratings of Pest Management Tools for pest nematodes in MI apple

Management Tools	Nematodes in Apple					
	Dagger	Root Lesion	Root Knot	Ring	Lance	Stunt
Organophosphates registered in MI						
fenamiphos (Nemacur 3)	F ¹	G	G	F	F	F
Carbamates registered in MI						
oxamyl (Vydate)	F	G	G	F	F	F
Alternative products registered in MI						
1,3-D (Telone)	G	E	E	G	G	G
methyl bromide (Nursery Stock)	E	E	E	E	E	E
metam sodium	G	E	E	G	G	G
Cultural Controls						
Cover crops	G	F	G	---	---	---
Soil Organic Matter	---	G	G	---	---	---
Nematode free rootstocks						

¹ Efficacy rating symbols: E = excellent, G = good, F = fair, P = poor, NC = not controlled, NU = not used

Table 5. Herbicide Effectiveness on Major Weeds in Tree Fruit Plantings

HERBICIDE	ANNUAL BROADLEAF								ANNUAL GRASSES							PERENNIAL WEEDS					
	Chickweed	Lambsquarters	Mustard	Pigweed	Ragweed	Smartweed	Horseweed	Yellow Rocket	Barnyard Grass	Brome Grass	Crabgrass	Fall Panicum	Sanbur	WiApplegrass	Foxtail	Bindweed	Chickweed	Dandelion	Golderod	Wild Grape	Ground Ivy
Casoron	E ¹	E	E	E	E	E	F	G	G	P	F	F		G	G	P	G	G		P	F
Devrinol	G	G	P	G	P	F	P	P	E	E	E	E		E	E	N	G	P	N		
Gallery	E	G	F	F	G		E		P		P				P		E	P			
Goal	G	E	F	E	G	G	F	F	F		F	F			F	P	G	P	N		
Surflan	E	G	F	G	P	P	P	P	G		G	G		E	E	N	G	P	N		
Kerb	G	P	F	F	F	F	P	F	E	E	E	G	E	F	G	N	G	N			
Simazine	E	E	E	E	E	E	F	E	E	F	F	F		F	E	F	E	P	N		
Solicam	G	F	F	F	F	G	F	G	G	F	G	G		F	E	P	G	P	N		
Fusilade	N	N	N	N	N	N	N	N	E	F	G	G		E	E	N	N	N	N		
Gramoxone Extra	E	E	E	E	G	E	G	G	E	E	E	E		E	E	P	P	P	P	P	P
Poast	N	N	N	N	N	N	N	N	E	F	G	E		E	E	N	N	N	N		
Rely	G	F		G	F	G	E	G	G	F	F	G	F		G	F	G	G	F		
Roundup Ultra	E	E	E	E	E	E	G	G	E	E	E	E		E	E	E	E	G	E	F	G
Touchdown	E	G	G	F	G	G		G	E	G	G	G		E	E	F	E	N			
2,4-D	P	F	G	G	G	G	P	G	N	N	N	N		N	N	G	P	E	P	F	P

¹Control ratings: e = excellent, g = good, f = fair, p = poor, and n = not labeled or no activity against this pest.

Table 5. Herbicide Effectiveness on Major Weeds in Tree Fruit Plantings (Cont.)

HERBICIDE	PERENNIAL WEEDS (CONT.)														
	Mallow	Milkweed	Nightshade	Nutsedge	Quackgrass	Plantain	Poison Ivy	Sowthistle	Stinging Nettle	CaNaphthaleneacetamide Thistle	Velvetleaf	VeApplehes	Virginia Creeper	Horsenettle	Shepherd's Purse
Gallery	P		G			G					G		N	P	G
Surflan	N	N	N	N	P		N	P		N	P		N	N	N
Simazine	N	P	G	P	F	P	N	F		P		P	N	P	G
Solicam	N	P		P	F	F	N	F		P	F		N	P	G
Fusilade	N	N	N	N	G	N	N			N	N		N	N	N
Gramoxone Extra	P	P	P	F	P	F	P	P	P	P	P	P	P	P	F
Poast	N	N	N	N	F	N	N	P		N	N		N	N	N
Rely	P	P	F	N	F	G	F	P	F	F	G	N	N	N	E
Roundup Ultra	F	E	E	F	E	F	E	G	F	E	G	F	G	F	G
Touchdown		F	G	F	G			E		F	F				G
2,4-D	P	P		P	N	E	F	F		G	G	F	P	P	G

¹Control ratings: e = excellent, g = good, f = fair, p = poor, and n = not labeled or no activity against this pest.

Table 6. Apple Variety Post-Harvest Disorders and Treatments*		
Variety	Diphenylamine (DPA)	Captan, Thiabendazole (Mertec), pyrimethanil (Penbotec)
Braeburn		Yes
Cortand	Scald	Yes
Empire	CO ² Injury	
Fuji	Scald	Yes
Gala		
Gingergold		
Golden Delicious	Scald Minor	
Granny Smith	Scald	Yes
Honeycrisp		Yes
Idared	Scald Minor	Yes
Jonagold		Yes
Jonathan	Scald Minor	Yes
McIntosh	Scald	Yes
Paulared		
Red Delicious	Scald	Yes
Rome	Scald	Yes
Winesap	Scald	Yes
Northern Spy		Yes

*Calcium is applied as a post-harvest drench on some varieties to improve storage and shelf life and reduce physiological disorders.

Effectiveness of Insecticides and Miticides in Controlling Arthropod Pests of Apples

(Note that a product's effectiveness rating on a pest does not necessarily indicate that it is labeled for that use.)

Insect/Mite		Life Stage	Insecticides/Miticides																																																		
			5	8	9	10	11	13	17	19	23	24	26	28	30	32	34	35	40	41	42	43	44	45	46	50	52	53	54	55	59	60	61	62	63	64	65	66	67	68	70	71	72	73	74	76	78	80	83	84	85	86	
Pests	Apple maggot	Adult	G	E	E	G	G	F	G							F	F	G					F	F			E			F	E	E	E	F	G	F	G			G		G		G		F	F						
	Codling moth	Larva	G	E	E	G	P		G				P		G	G	G						G	F	G	F					E	E	F	G	G			G	G	E	G		G	G	F/G	F/G	E						
	Cutworms	Larva	P		F								E	E	E	E						E		G								G	E						E			E						E					
	European red mite	Active			F			E		E	E	G						E	E			G	E					F			G						G					E	E										
	Green apple aphid	Active		P	P	P		G	P	E	P	P	F		G		F	F	F												G	E	E	E							E												
	Green fruitworm	Larva	F	P	P	G					F	P	E	E	E	E						G	E		G	G	G							G	E			E		E	G	E	E	E	E	E	E	E					
	Obliquebanded leafroller	Larva	G	E	E	G					P	E	E	E	E	E						G	E		E	E	F				F					E	G			G	G	G	G	G	E	E	E	E					
	Oriental fruit moth	Larva	G	E	E	G				G								G						G	F	G	F				G			F	G			G	G	G	G	G	G	F/G	E	G							
	Plum curculio	Adult		E	E	F	P		F	F			P		G	G	G						G					F	P	E	G	E				G			G	E		G		G		F	G						
	Leafrollers	Larva	G	E	E	E	P		F				P		E	E	E					G	E		E	E	G				G			E	E			E	E	E	E	E	E	E	E	E	E	E	E				
	Rose chafer	Adult							G	G								G					G					F	F	G	G	G			G			G			G		G		G					G			
	Rosy apple aphid	Active	P	P	P	G	P		E	P	E	E		G	E	F	F	F										G			G	E	E	E							E												
	Rust mite	Active	P	P	P	F		F	G		E	G	F		P	P		G	F												G											G		E	E								
	San Jose scale	Adult									E			E	P	P	P																	F			G																
	San Jose scale	Crawler	G						F						P	P	P											G								E								E	G								
	Spotted tentiform leafminer	Adult		P		F						F			P	E	E	E						E																		E		E		E	E		E				
	Spotted tentiform leafminer	Larva	P			E			E		P	E		P	P	P	E									E	G	G				E	E	E	E	P		P	E	G	P	P	P	G	E	P							
	Tarnished Plantbug	Active	P	P	P	G			G		F			E	E	E								E					G	G	G	G					E			E		E		E		E				E			
	Twospotted spider mite	Active				G	E				G	F						E	E				G	G																		E		G		F							
	White apple leafhopper	Active	P	P	P	E	P		E	E	F		E		P	P	G	G					G	F					G		F	E	E				G			G	E		G		G	F	G			G			
Woolly apple aphid	Active	F			P			G	F	E		P	E	P	P																																						
Beneficials	Bees		T	T	T	T	T	S	T	T	S	M	S	S	T	T	T	T	T	S	S	T	M	M	S	S	N	S	M	T	S	M	M	S	M	S	T	S	S	T	M	S	T	S	T	M	T	S	T	T			
	Mite predators		S	S	S	M	T	M	S	S	T	S	M	S	T	S	T	T	T	S	S	S	T	M	S	S	S	M	S	S	S	S	S	S	S	S	S	S	T	S	S	T	S	S	T	S	S	T	M	T	S	S	T
	Insect Predators		T	M	M	N	T	M	S	M	T	S	M	S	T	S	T	T	T	S	S	S	T	M	M	S	S	M	S	S	M	M	S	M	S	S	T	S	S	T	M	S	T	S	T	M	T	S	S	M	T		

¹ Use only before pre-pink!

Table 8. Toxicity of pesticides to mite and aphid predators

Material	<u>Mite Predators</u>				General	
	Stethorus adults	Stethorus larvae	Amblyseius fallacis	Zetzellia mali	Aphid- oletes	aphid predators
Insecticides/miticides						
Abamectin	++	++	++	++	-	-
Clofentezine	0	0	+	+	+	+
Esfenvalerate	+++	+++	+++	++	++	+++
azinphosmethyl	+	+	+	+	+++	++
Bt	0	0	0	0	-	0
Carbaryl	+++	+++	++	++	+++	++
Formetanate HCL	+	++	+++	++	-	++
Chlorpyrifos	+	+	++	++	-	++
Dimethoate	+	+	+++	-	+++	++
Diazinon	+	+	-	-	+++	++
Endosulfan	++	++	+	-	++	++
Phosmet	+	+	+	+	0	+
Dicofol	+	+	++	+	+	+
Methomyl	++	++	+++	++	+++	+++
Malathion	-	-	-	-	-	-
Soap	++	++	-	-	-	++
Methyl parathion	+	+	+	+	+	++
Permethrin	+++	+++	+++	++	+	++
Imidacloprid	++	++	+	+	-	++
Pyridaben	++	++	-	-	-	++
Hexythiazox	0	0	+	+	-	+
Oil	+	+	++	++	-	++
Fenbutatin Oxide	+	+	+	+++	+	+
Oxamyl	++	++	+++	+++	++	++
Spinosad	0	0	0	0	0	0
Tebufenozide	0	0	0	0	0	0
Methoxyfenozide	0	0	0	0	0	0
Indoxacarb	++	++	+	+	++	++
Triazamate	+	+	+	+	+	+
Acetamiprid	++	++	+	+	++	++
Fenoxycarb	+++	+++	0	0	+	++
Pyriproxyfen	++	++	0	0	+	++
Emamectin	+	+	0	0	?	?
Kaolin	+++	+++	?	?	?	++
Pirimicarb	+	+	+	+	+	+

+ = slightly toxic, ++ = moderately toxic, +++ = highly toxic, - = no data available, 0 = nontoxic

b General aphid predators include coccinellids, lacewings, syrphid fly larvae, minute pirate bugs, and mullein bugs.

From: **The Foundation for a Transition Strategy for Lessening Dependency on Organophosphate Insecticides in the Mid-Atlantic/Appalachian/Southeastern Apple Production Region Document** by N.Anderson, R.Bessin, M.Brown, W.Burr, J.Cranney, E.Dabaan, L.Giannessi, H.Hogmire, L.Hull, M.Lynd, B.Reid, J.Walgenbach, T.White.

Table 9. Contacts and Contributors to 2000 PMSP Background Material

**Apple Pest Management Strategic Plan
Workgroup Invited Participants, June 28, 2000**

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