Updates to
2008 Michigan Apple PMSP

September 2011

PREVIOUS PEST MANAGEMENT STRATEGIC PLAN

The previous Pest Management Strategic Plan (PMSP) was developed to document the pest management needs of Michigan's apple industry and to help address the industry's pesticide use issues. The previous apple PMSP was accomplished in a series of steps. The process and initial framework was approved by the Michigan Apple Research Subcommittee in March 2000. A committee consisting of MI apple growers, Michigan State University extension specialists and educators, and representatives of the Michigan Apple Committee, Michigan Processing Apple Growers, MI Agricultural Cooperative Marketing Association, Inc., the Michigan State Horticultural Society, and the MI Farm Bureau held four workshops in the Winter and Spring of 2008 to review and revise the PMSP document originally begun in 2000. The 2008 PMSP was published on the Michigan Apple Committee website as a means of making it widely available to the Michigan apple industry. Feedback from the industry was incorporated into the document and the final PMSP was submitted to the US EPA in the Fall of 2008. The aim of the PMSP was to 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 final document was designed to effectively and economically address pest management issues that impact industry viability and to lessen dependency on organophosphate and carbamate insecticides and B2 fungicides in apple production.

OUTCOMES

The following section describes the progress completed for the priorities from the 2000-2008 Apple PMSP.

Research Priority (Insects): Develop and implement economic and effective OP-alternative and Reduced Risk strategies for in-season control of internal fruit feeding pests under MI 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)**

MSU faculty and staff have a robust program for testing the efficacy of new insecticides and understanding their lethal and sublethal effects. Experimental and recently registered compounds are evaluated in small plot and on-farm research trials. Over 50 trials per year are conducted at MSU research stations and on-farm research is conducted annually on over 20 farms. Field-lab bioassays are conducted to understand how the new insecticides work. Research conducted at Michigan State University has helped in obtaining labels for several new products, including spinetoram (Delegate), rynaxypyr (Altacor), flubendiamide (Belt), and spirotetromat (Movento).

Research Priority (Insects): 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) Improve knowledge of adjacent landscape (areawide) effects on IPM**

Functional ecology is a very powerful tool for diagnosing the environmental and ecological conditions of an orchard when compiled across time, location, and various blocks. This provides fruit growers with the advantage of having a measure or indicator of how environmentally healthy or sustainable a production system is. An important part of functional ecology assessment is the monitoring of natural enemies in orchards. As part of two RAMP (Reduced Risk Management Program) projects, natural enemy surveys were conducted through the growing season in both reduced-risk and conventional orchards. Natural enemy acitivity was similar under the two management regimes. More research is needed to understand the effects of new reduced-risk insecticides on predators and parasitoids. A 4-yr research and implementation project in Michigan apple production showed that deploying pheromone-mediated mating disruption for codling moth, *Cydia pomonella* L., in an areawide (AW-CMMD) program where mating disruption is established on all apple-producing acreage on individual and adjacent farms, significantly improves control of codling moth. Captures of male codling moth in pheromone-baited traps were reduced 93% by year 4 of the project in AW-CMMD orchards. Injury to fruit and the overall number of insecticides targeting codling moth decreased each year in the areawide program. Growers who implemented AW-CMMD realized a mean savings of $55–65/ha through reduced fruit injury and use of insecticides as compared with orchards using insecticide-only programs. This Michigan project demonstrates that an areawide approach to mating disruption improves the benefits of deploying pheromone in individual blocks.

Research Priority (Insects): Develop monitoring and control strategies for secondary pests previously controlled by OP's (including leafrollers, pest mites, borers, Japanese beetle, woolly apple aphid, scale, true bugs).

Management of secondary pests is an on-going research priority for the Michigan apple industry. Leafrollers have historically been especially problematic. However, several recently registered insecticides, including rynaxypyr and spinetoram, are highly efficacious against this pest complex. Unfortunately, leafrollers have the propensity to develop resistance fairly quickly. Growers must follow a sound leafroller resistance management program by rotating compounds with different modes of action. MSU researchers have demonstrated that mating disruption is a potential option for managing dogwood borer. Some newer insecticides have proved to be disruptive to spider mite and woolly apple aphid control. Growers are learning how to incorporate these controls into their management programs at timings that avoid negative impacts on non-targets.

Research Priority (Insects): Continue evaluation of breeding potential for genetic traits in apple rootstock and cultivar that could confer resistance to insect pests.
MSU currently does not have the capacity to conduct research on breeding for resistance. Washington State University has recenly expanded their capacity to breed for genetic traits in apple rootstock and cultivar that could confer resistance to insect pests.

Research Priority (Insects): Identify resistance genes that could be introduced to desirable cultivars.
A national program to evaluate the apple genome is ongoing.

Research Priority (Insects): Implement new cultural practices, including strategies of orchard floor management that enhance insect control.
This remains a research priority.

Research Priority (Diseases): 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 MI conditions**
c) **Identify efficacious material for the control of shoot and trauma blight**

The antibiotic kasugamycin (Kasumin; Arysta LifeScience) was field tested yearly for efficacy at MSU from 2008 through 2011 and in all cases showed similar efficacy to streptomycin in blossom blight control. Based on this research, Dr. Sundin provided data and assisted in writing a Section 18 emergency exemption application for Kasumin use with the Michigan Department of Agriculture. Kasumin is now utilized for fire blight in counties where streptomycin resistance has been confirmed under a Section 18 specific exemption granted by the EPA in 2010 and 2011. Arysta LifeScience has applied for a full Section 3 registration for the use of Kasumin for fire blight control on pome fruits. Biological control agents that are used in the Pacific Northwest including Bloomtime Biological and BlightBan were field tested for efficacy at MSU. These materials did not adequately control fire blight under Michigan conditions. The function of prohexadione calcium (Apogee) for shoot blight control was studied and shown to be due to increasing plant cell wall widths. Prohexadione calcium is the only efficacious shoot blight material available to apple growers currently.

Research Priority (Diseases): Investigate fungicides to replace carbamate and B2 fungicides and for rotation with copper, strobilurin, and boscalid fungicides.
The 2nd generation sterol inhibitor compound difenoconazole which is present in Inspire Super (Syngenta Corp.) was shown to be effective in apple scab control in field trials in orchards where sterol imhibitor-resistant isolates were present. Other fungicides in the boscalid class (penthiopyrad, fluopyram, fluxapyroxad) were field tested and also shown to be effective. These fungicides are important for their excellent scab control and that cross resistance among this fungicide class does not always occur. There are currently no effective broad-spectrum fungicide alternatives to the current B2 fungicides.

Research Priority (Diseases): Develop programs to reduce reliance on single-site fungicides and to delay the development of resistance.
No new broad-spectrum fungicides have become available for apple scab control. We are currently experimenting with various mixtures of fungicide modes of action to delay resistance development.

Research Priority (Diseases): Evaluate efficacy and economics of alternate row vs. full cover fungicide applications.
This work is currently underway at one MSU Research Station, data and outcomes are expected available in the Fall of 2011.

Research Priority (Diseases): Screen for strobilurin and boscalid resistance.
This work is underway. In 2008 and 2009, we detected widespread strobilurin resistance in the apple scab pathogen throughout Michigan. Growers were immediately advised to discontinue use of this fungicide class. Screening for boscalid resistance in apple scab was initiated in 2011.

Research Priority (Diseases): 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

Michigan State University does not currently have an apple breeding program.

Research Priority (Diseases): Implement new cultural practices, including strategies of orchard floor management that enhance disease control.
Cultural practices for leaf litter control for overwintering apple scab has been reintroduced to growers due to the problems with fungicide resistance. Research in apple canker pathogens and their potential movement in symptomless apple tissue is guiding work on various pruning techniques for canker disease control.

Research Priority (Diseases): Develop and implement new fungicides and biological control agents for post-harvest disease control.
Post-harvest disease control research has not been conducted in Michigan, but this remains a research priority.

Research Priority (Weeds, orchard floor, and soil pest management): Evaluate and implement new weed physical, chemical and biological control strategies, tactics and tools. This work is currently being completed through ongoing research at MSU.
MSU weed scientists continue to work with new compounds registered for weeds in apple orchards and work through the IR-4 program to identify new label additions.

Research Priority (Weeds, orchard floor, and soil pest management):Evaluate and implement compatible ecological systems that favor pollination, biological control and sustainability.
Work continues in identifying refuge strips for conservation of beneficial insects.

Research Priority (Weeds, orchard floor, and soil pest management):Evaluate and implement orchard floor systems that manage weeds while providing habit favorable to development of beneficial soil organisms.
Currently no work is being done in this area, but it remains a priority for the apple industry.

Research Priority (Pollination): Develop and implement pollination strategies and tactics that are compatible with pest management (pollination/natural enemy plant strips, alternate row mowing, etc.).
MSU researchers are investigating the role of native pollinators, as well as the use of attractants to enhance pollination. Bee activity is monitored during bloom to rate pollination. Growers are educated on when to have bees removed prior to potential harmful pesticide applications.

Research Priority (Wildlife): Develop and implement alternatives for deer management (e.g. fencing and repellents).
MSU does not develop or implement deer management, but rather focuses on continued contact with funding agencies to keep this issue in the forefront.

Research Priority (Wildlife): Develop and implement alternatives for control of mice and voles.
Currently, no one at MSU is doing work in this area, but it remains a priority for the apple industry.

Research Priority (Horticultural): Evaluate breeding potential for genetic traits in apple that could confer rootstock and cultivar resistance to reduce or eliminate physiological disorders.
MSU does not have an apple rootstock or cultivar breeding program.

Research Priority (Horticultural): Evaluate orchard systems and new production technologies.
Tree production systems are currently being researched at MSU. MSU is also working with companies that produce new technology by introducing them through field days and orchard demonstrations.

Research Priority (Horticultural): Evaluate new materials and strategies for growth regulation (i.e., apple thinning, shoot growth, etc.).
MSU continues work on existing, labeled growth regulators as well as those in development. There has been talk of losing Sevin as a thinner in apples and since this is a primary product in apple growers' thinning toolbox, alternatives are being looked at for their potential use. Several years of data are needed to fine-tune the use of a thinner for apple production.

Research Priority (Horticultural): Develop better understanding of nutritional disorders (eg., bitter pit).
MSU has ongoing research projects in this area.

Regulatory Priority: 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.
This is the top regulatory priority. Within the last three years, Maximum Residue Levels (MRLs) have emerged from an obscure concept to become a critical concern to Michigan's fruit growers, packers and exporters. As it pertains to fruit exports, MRLs are becoming the nontariff trade barrier of our times. To maintain international markets for Michigan Apples, it is crucial that the speed of US regulatory changes and phase-outs for pest control products does not exceed the speed at which MRLs are harmonized abroad – which is a very slow, tedious and competitive process. With the impending loss of azinphosmethyl after the 2011 growing season, the vast majority of OP alternative and reduced-risk pesticides either do not have MRLs established in the countries to which MI is exporting, or their tolerances in the desired export market are significantly below the accepted US residue tolerance – the spray level for which is needed to actually control the insect pest.

Regulatory Priority: 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.
This also is a regulatory priority. Michigan, as well as other eastern apple production regions, have a much more extensive pest and disease complex. With the impending loss of AZM after the 2011 growing season, Michigan's apple industry cannot survive with the alternatives currently in place. EPA must take a regional perspective in developing and implementing regulatory needs to promote national parity.

Regulatory Priority: Increase cost sharing for implementation of IPM technologies (weather and others).
This remains an industry priority. An MSU-supported Enviro-weather program is a key component of apple IPM programs in Michigan.

Regulatory Priority: 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.
IR-4 continues to be a priority program for the apple industry.

Regulatory Priority: 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.
This program has been implemented by the US EPA, but companies are reluctant to engage in the process.

Regulatory Priority: Ensure nursery stock is virus-tested for all known viruses.
Progress has been made, but efforts are often limited by funding.

Regulatory Priority: Implement and fund enforcement of laws regulating neglected orchards.
This is a state issue that is being worked on.

Regulatory Priority: Construct and maintain endangered species maps and endangered species corridors that are reasonably precise (township level).
This remains an industry priority.

Educational Priorities:

a) **Expand information on new pest management advances for growers, consultants, and scouts.**

Campus and field-based research and extension specialists contribute content regarding pests, production, and marketing problems. Weekly conference call are held to to discuss conditions and appropriate IPM strategies. This team publishes the MSUE News for Agriculture, which is viewed weekly by over 1000 people (2010).

b) **Improve delivery of real-time pest management information to the agricultural community.**

An MSU Fruit Area of Expertise Team (AOE) comprised of the campus and field-based research and extension specialists enhances 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 team publishes the MSUE News for Agriculture, which is viewed weekly by over 1000 people (2010).

c) **Offer apprenticeship programs for scout training.**
d) **Help develop and educate a healthy private consultant industry.**
e) **Inform landowners about issues and laws regulating neglected orchards.**
f) **Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.**
g) **Provide hands-on educational opportunities for regulators and policymakers.**

Educational priorities are met through a number of methods including publications, television appearances, and speaking engagements. MSU Extension fruit and IPM specialists and educators have made a significant effort to train scouts and work closely with private sector consultants, providing training and information. Some examples are: 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, hold regional breakfast and evening meetings to keep local consultants and growers apprised of developments in their areas. The Michigan IPM Alliance and Michigan State University annually conduct a decision makers tour for regulators and policymakers to provide hands-on education relative to the pest management issues facing Michigan's specialty crops.

REVISED PEST MANAGEMENT STRATEGIC PLAN

The Pest Management Strategic Plan (PMSP) was revised in 2011 to address the industry's critical pesticide use issues and to document changes in the pest management needs of Michigan's apple industry. The revised PMSP was developed by a team of MI apple growers, Michigan State University extension specialists and educators, and representatives of the Michigan Apple Committee, Michigan Processing Apple Growers, MI Agricultural Cooperative Marketing Association, Inc., the Michigan State Horticultural Society, and the MI Farm Bureau. In addition to updating and prioritizing regulatory, research, and educational needs for addressing critical pest management issues, the aim of the revised PMSP is to **serve as the guide for the USEPAs' decision-making process**. Thus, the regulatory challenges facing the industry have been given added attention in the revised document. An area of significant concern for MI apple growers is the impending loss a key pest management tool, azinphosmethyl. Prior to cancelling this registration there must be harmonized MRL's for the alternatives and there must be effective and economical alternative controls for plum curculio, apple maggot, brown marmorated stinkbug (BMSB), Japanes beetle and other adult pests. As it pertains to fruit exports, MRLs are becoming the nontariff trade barrier of our times. To maintain international markets for Michigan Apples, it is crucial that the speed of US regulatory changes and phase-outs for pest control products does not exceed the speed at which MRLs are harmonized abroad – which is a very slow, tedious and competitive process. Over the past few years, invasive species have had economically severe impacts on North American fruit crop industries. Among the 10-15 invasive species that potentially attack these crops, the BMSB is the most well documented and high profile threat to the Michigan apple industry. The establishment of BMSB, Light Brown Apple Moth, or another invasive species in Michigan would greatly compromise the IPM programs developed for insect management in apple, increasing the need for monitoring, chemical applications, and extension education programs. 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. An informed decision-making 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 are profitable, reduce reliance on FQPA-targeted pesticides, address resistance issues, etc.

<u>Michigan Apple</u>
<u>Pest Management in the Future</u>
<u>A Strategic Plan</u>

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 Review/Submission:	July-Sept, 2008
Industry Update/Review/Submission:	June-Sept 2011

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TABLE OF CONTENTS

Section I. Pest Management Priorities

Introduction

Apple is susceptible to several key pests including insects, diseases, nematodes, and weeds. It is critical that these key pests be effectively controlled to maintain adequate yields of quality fruit that is acceptable to consumers. Over time, an apple production system that relies on applications of broad-spectrum pesticides to control these pests has evolved. These materials have provided good control for over 40 years, but many factors acting together 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 arrival of invasive insect pests such as brown marmorated stink bug and spotted wing drosophila has added an additional layer of complexity to the goals of the apple industry and could potentially threaten many of the current IPM strategies commonly utilized. Apple growers have responded 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.

An unintended marketplace consequence of these changes in crop inputs and pests is the threat to MI apple exports. Before registration are cancelled, the USEPA needs to collaborate with industry and US Codex negotiators to ensure that appropriate harmonized maximum residue levels (MRLs) are established for replacement chemistries. The phase-out of azinphosmethyl has already blocked or slowed exports of MI blueberries and cherries, and threatens to do the same to apples The agency should also recognize the needs of western and eastern states' growers are significantly different due to climate.

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. The apple pest management strategic planning process was undertaken by the industry to help identify the need for alternatives to replace pesticide control tools at risk due to resistance, reregistration, invasive species, maximum residue limits (MRLs), and to address the discrepancies of Codex Alimentarius. 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.

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 fruit feeding pests under MI climactic conditions.
    a) Evaluate insecticides not currently labeled for apple, particularly those with activity against insects that need to be controlled in the adult stage. Currently, no insecticides that adequately replace azinphosmethyl have been developed for this group of pests.
    b) Understand how new insecticides work and how this impacts application timing.
    c) Develop and test economical and highly effective mating disruption technologies (especially machine applied, multi-species, and other formulations that reduce application costs)
    d) Develop and integrate new control tactics in a biologically 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) Non-target impacts of new insecticides and 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. Monitoring for invasive and emerging pest species and develop control strategies for new invasives that will maintain economically viable IPM programs. The Brown Marmorated stinkbug has recently been detected in Michigan and represents a serious threat to the apple industry. The Light Brown Apple moth has recently been detected in California and is a quarantine pest.
5. Identify resistance genes and continue evaluation of breeding potential for genetic traits in apple rootstock and cultivar that could confer resistance to insect pests.
6. Implement new cultural practices, including strategies of orchard floor management that enhance insect control.
7. Optimize pesticide delivery of reduced risk materials while minimizing negative effects on workers, environment and non-target organisms: 1) Solid Set Delivery Systems, 2) Trunk Injection, 3) Improve ground sprayer technologies.
8. Determine the rainfast characteristics of pesticides to guide grower management decisions.

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 MI conditions.
    c) Identify efficacious material for the control of shoot and trauma blight

2. Investigate new fungicides for scab and mildew control. There is a pressing need 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 fungicide resistance in the apple scab pathogen.
    a) screen for resistance to boscalid and new fungicides, including penthiopyrad and fluopyram.
    b) screen for anilinopyrimidine resistance.
    c) Continue strobilurin resistance screening.
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.
9. Determine the impact of antibiotic use on apple orchard microflora.
10. Determine the prevalance and impact of apple canker fungi and develop management programs for pathogen erradication.

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.
3. Develop and implement alternatives for control of crows, turkeys and other birds.

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.)

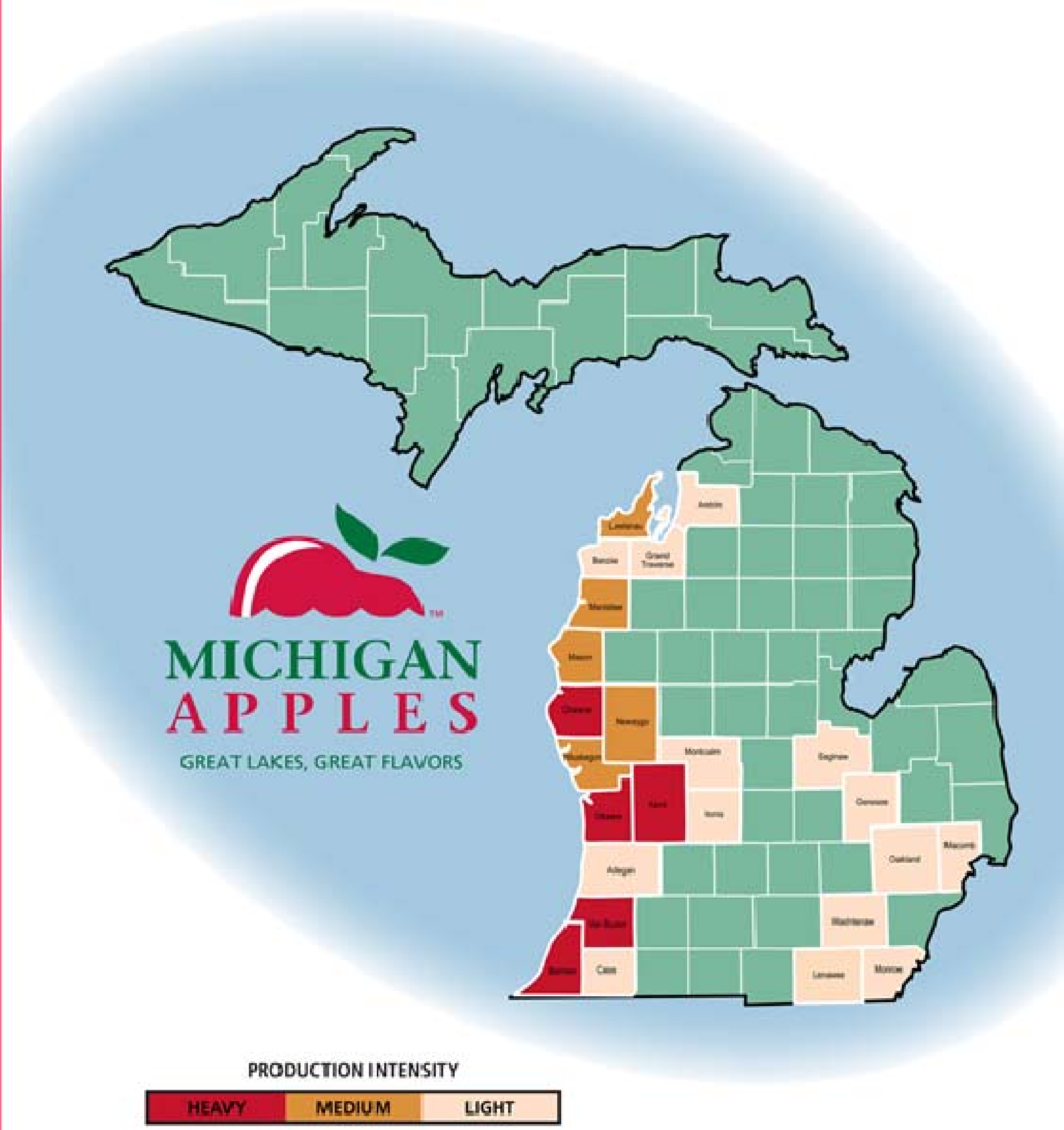
Regulatory

1. Michigan needs to have the current use of azinphosmethyl maintained past the 2012 phase-out date. Prior to cancelling this registration there must be harmonized MRL's for the alternatives and there must be effective and economical alternative controls for plum curculio, apple maggot, Brown marmorated stinkbug, Japanes beetles and other adult pests.
2. Michigan needs to be on a level playing field with international competition when it comes to chemical restrictions. For example, competing countries have the ability to use EBDC fungicides for longer periods and in greater quantities than US apple growers. EPA needs to ensure parity with imports and accomodate US apple production by helping the industry transition to tools that have harmonized MRLs in foreign markets.
3. 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.
4. Facilitate, engage and increase funding to the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacement insecticides, viable fungicides bactericides, and herbicides.
5. Improve current EUP process for evaluating new pesticides on farms before registration by developing and supporting a program that will allow researchers to test new chemistries on prior to full registration.
6. Ensure nursery stock is virus-tested for all known viruses.
7. Implement and fund enforcement of laws regulating neglected orchards.
8. Increase cost sharing for implementation of IPM technologies (weather and others).
9. Construct and maintain endangered species maps and endangered species corridors that are reasonably precise (township level).

Education

1. Expand information on new pest management tactics and strategies for growers, consultants, and scouts.
2. Improve delivery of real-time pest management information to the agricultural community.
3. Offer apprenticeship programs for scout training.
4. Help develop and educate a healthy private consultant industry.
5. Inform landowners about issues and laws regulating neglected orchards.
6. Educate general public on modern fruit production, local production techniques, and health and economic benefits of Michigan apples.
7. Provide hands-on educational opportunities for regulators and policymakers. x

MICHIGAN APPLES



Farms: 900 • Acres: 37,000 • Farm Markets: 200 • Annual Economic Impact: $700 -$900 million

Section II – 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 18.95 million bushels (796 million pounds) for the five-year period from 2006-2010.
- The average value of production during the years 2006-2010 was $120,992,000 per year. Apples have an economic impact of ~ $800 million annually.
- Over 7.6 million trees are planted on nearly 900 farms comprising approximately 37,000 acres of orchard (MASS 2007).
- The average utilization of Michigan apples during 2006-2010 was 35% for fresh market and 65 % 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 1 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 higher elevation areas 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 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 training are important cultural practices. 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 prior to pesticide applications. Training is done throughout the year,

but primarily in non-bearing blocks with a very reduced pest control program. Summer pruning takes place in August in about 15% of the states apple acreage.
- To be profitable and productive, apple growers aim to 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. An estimated 10% of the apple acreage is hand-thinned.
- Pre-harvest growth regulator applications to enhance fruit color and harvesting are also used in some blocks.

Important Pest Management Issues

Pest complex

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. Weeds can reduce productivity up to 60% if not controlled adequately.

Phase-out of azinphosmethyl

An area of significant concern for MI apple growers is the impending loss a key pest management tool, azinphosmethyl. Prior to cancelling this registration there must be harmonized MRL's for the alternatives and there must be effective and economical alternative controls for plum curculio, apple maggot, brown marmorated stinkbug, Japanes beetle and other adult pests. For example, neonicotinoids (Assail and Calypso) are the primary reduced-risk alternative for apple maggot control. These compounds appear to provide control, in part, by repelling or deterring the adults, rather than by killing them. Apple maggot populations have annually increased in the state over the past 5 years, most likely due to reduced use of azinphosmethyl and greater reliance on alternatives. It may only be a matter of time before populations reach densities that result in worms being present at harvest.

In an exhaustive grower survey performed collaboratively by Michigan Apple Committee and Michigan State University in the Fall, 2009 (submitted to Mr. Richard P. Keigwin, Director, Special Review and Re-registration Division, USEPA, on February 17, 2011) growers overwhelmingly believed the EPA had underestimated the economic impact of this phase-out. The survey revealed that 60% of MI commercial apple growers saw their pesticide costs increase 50% or more. Over half of this subset said their pesticide costs were up by 75% or more. This is much greater than the 5-18 percent range of losses predicted in EPA's 2005 BEAD analysis. A Michigan State University-determined cost of production study confirms that pesticide cost has increased significantly as a percentage of total production costs since 1998 – and comprises the only category showing and increased share of production costs. This is highly significant for MI growers, as the average net revenue or profit per acre is only $800. Thus, increases in pesticide costs associated with using more expensive replacements for azinphosmethyl substantially reduce profitability.

Invasive species

Over the past few years, invasive species have had economically severe impacts on North American fruit crop industries. Among the 10-15 invasive species that potentially attack these crops, the Brown Marmorated Stink Bug (BMSB) and the Light Brown Apple Moth (LBAM) are the most well documented and high profile threats to the Michigan apple industry. To date, BMSB has been recorded from a majority of the East coast states and in all states bordering Michigan. In just 10 years populations have reached high enough numbers to cause substantial damage in New Jersey, Maryland and Pennsylvania tree fruits. Growers in these regions are abandoning IPM programs and moving to weekly sprays in an attempt to save their crop. The BMSB was detected in 4 Michigan counties in 2011. In the state's southern tier counties, suspicious damage has been observed in several apple orchards suggesting that the BMSB may be building in numbers sufficient to cause crop loss. The LBAM is native to Australia, but recently has been detected in California, affecting the state's apple, grape and ornamental industries. Larvae feed on foliage, buds, shoots, and the surface of host plant fruits. The LBAM is a quarantine pest, which means that orchards with this pest could be quarantined by the USDA, an economically devastating turn of events for a producer. Following LBAM's detection in CA, the State implemented a massive eradication program to protect their multi-billion dollar agriculture business, with only limited success. The establishment of BMSB, LBAM or another invasive species in Michigan would greatly compromise the IPM programs developed for insect management in apple, increasing the need for monitoring, chemical applications, and extension education programs.

Codex Alimentarius Harmonization Lag

In 1963, the Codex Alimentarius Commission (CAC) was established through a collaboration of the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) to institute food standards, codes of practice, and guidelines. The CAC promotes coordination of food standards for international government and non-governmental organizations, such as maximum residue levels (MRLs) allowed on fruit at the time of processing for international and regional trade. Each country has its own regulations for MRLs and if a country does not have their own MRLs established, they will often use those set forth by the Codex Alimentarius (CA). In certain instances these are lower than the United States-maintained MRLs, which can inhibit American growers from selling their product in these national markets.

The United States Environmental Protection Agency's (USEPA) phase-out of AZM under the Food Quality Protection Act (FQPA) has forced growers to turn to alternative chemistries that leave higher residues on apples. With higher MRLs, American growers cannot market their products in international marketplaces as easily. Other countries with the use of AZM can, however, sell their product in American markets because with the use of AZM they can meet the United States maintained MRLs. Domestic growers now lose out on money from export and must compete domestically with each other and foreign importers. A strategic plan to harmonize the discrepancies between international MRLs must be established and implemented in order to protect domestic apple growers and to improve their international economic competitiveness.

Michigan apple IPM

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 mites by severely limiting use of carbamates and synthetic pyrethroids because these compounds are highly toxic to beneficial mites.
- 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 tactics 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 pest and crop forecasting tools (Enviroweather)
- Alternate row spraying
- Border and partial block or "hot-spot" spraying
- Use of air-curtain and "smart" sprayers
- Use of *MSUE News for Agriculture (*over 1000 weekly viewers per issue; internet and print)
- Increased use of selective and “softer” materials

- Reliance on pheromone-based mating disruption for control of CM
- 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. More recently, implementation of mating disruption on an areawide basis allowed for a 50% reduction in the use of broad spectrum insecticides. 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 Michigan Apple Committee (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 Rural Development (MDARD) and Michigan State University, which is dedicated to increasing implementation of IPM in Michigan.

Research funds available through MAC, the Michigan State Horticultural Society (MSHS), MI Project GREEEN (Generating Research and Extension to meet Economic and Environmental Needs), and private industry to address critical pest management issues are limited. The MSU AgBioResearch (formerly Michigan Agricultural Experiment Station) 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 Center, Fennville). The MSU AgBioResearch, in conjunction with private and public agencies (MDARD, EPA, USDA), initiates and supports many IPM-related research projects. A state initiative, Project GREEEN, 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.
- An MSU Fruit Area of Expertise Team (AOE) comprised of the campus and field-based research and extension specialists enhances 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 team publishes the *MSUE News for Agriculture*, which is viewed weekly by over 1000 people (2010).

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.

Michigan State University hired an Organic Pest Management Specialist in 2008. Current work includes innovative organic pest management systems, biology and control of new emerging pests and manure and weed control. The organic specialist serves in an advisory capacity to several national organizations.

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.

The Strategic Plan is intended to be the principle source of information on MI apple production and pest management, including the needs and challenges facing growers. Furthermore, it should serve as the guide for the USEPAs' decision-making process impacting the MI apple industry. The most direct impacts are the loss of registrations and the speed of registering new pesticides. These actions also have often overlooked consequences that impact growers, shippers and the ability to sell in the international marketplace. Of particular importance is the need to ensure harmonized MRLs.

Summary of Planning Process

The overall goal of the pest management strategic planning process has been 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 has been to develop a document that provides the foundation for a Pest Management Strategic Plan that will:

a) serve as the guide for the USEPAs' decision-making process
b) effectively and economically address pest management issues that impact industry viability
c) help the apple industry incorporate new chemistries and technologies into their apple IPM programs.

Work Plan

Development of a Pest Management Strategic Plan for Michigan Apples was accomplished in a series of steps. A committee consisting of MI apple growers, Michigan State University extension specialists and educators, and representatives of the Michigan Apple Committee, Michigan Processing Apple Growers, MI Agricultural Cooperative Marketing Association, Inc., the Michigan State Horticultural Society, and the MI Farm Bureau gathered 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 Subcommittee recommended to the MAC 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. The first PMSP was held at the MSU Clarksville Research Center in 2001, focusing on insect pest control. The final document was submitted to the MI apple industry. The

2008 PMSP included all aspects apple pest management (e.g., insects, diseaseas, weeds, horticultural inputs, etc.) The final document was published on MAC's website and publicized in their newsletter to solicit grower input. After incorporating grower input, the PMSP was submitted to the USEPA. The document was revisited and substantially revised in the Summer of 2011.

<u>The document developed was guided by the following principles:</u>
1. Profitability for apple growers is the key element of the strategic plan; cost-effective alternative pest management tools and programs that allow the MI apple industry to be competitive nationally and internationally (e.g., harmonized MRLs).

2. Geographical regions within Michigan are considered when developing strategies due to differences in environmental/climatic conditions, production practices, pest complex and pressure, crop varieties, and marketing opportunities.

3. The PMSP serve as the guide for the USEPAs' decision-making process

4. A major outcome of the document is to identify and prioritize research areas, regulatory actions, and educational programs required as apple growers improve current IPM programs that emphasize reduced pesticide use, and greater reliance on USEPA reduced risk pesticides and new technologies.

5. Pest management programs consider worker protection, food safety, endangered species, and environmental/ecological issues.

6. The completed plan has 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.

Section III - Apple PMSP: Foundation of the strategic plan

Insect 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

- **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 peek emergence is typically the middle of August. The same infestation cycle is repeated, with the pupa over wintering 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.

❖ **Wooly apple aphid (WAA)**

- There are typically 3 to 4 generations of wooly 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.

Management plans for the major insect pests

The following 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 insect 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 product-on regions.
- ❖ Several insecticides that are effective OP alternatives for CM control have been registered over the past five years, however they are generally 2-3 times 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)
  - Highly effective against susceptible populations with up to 2 weeks of residual activity depending on weather.
  - Field failures have occurred and resistance in all MI 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 widespread 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)
- Provides good control 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.
- Provides good control 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), and othets.
- 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, Belay)
- 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.

❖ Spinetoram (Delegate)
- A highly effective insecticide for both first and second generation CM control
- Another formulation of spinosad, Entrust, is organically approved.
- Up to three times as expensive as older chemistries

❖ 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.
    - Up to three times as expensive as older chemistries.
- Flubendiamide (Belt)
    - A highly effective insecticide for both first and second generation CM control.
    - Same mode of action as rynaxypyr, and thus a good resistance management option.
    - Up to three times as expensive as older chemistries.
- ❖ Indoxacarb (Avaunt)
    - Small-plot and on-farm research conducted in MI 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 MI.
    - 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

❖ Cyazypyr
  - Research trials indicate efficacy against both first and second generation CM.
  - Mode of action is the same as rynaxypyr, thus a good resistance management option.
  - Anticipated registration in 2013; 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 cyazypyr.
- ❖ Improve degree-day models and monitoring systems to improve the utility of pheromone traps as a basis for management decisions.
- ❖ Develop and 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 'reduced-risk' chemistries.
- ❖ 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 mid- to 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 as this class of compounds are still highly effective; 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 2-3 times 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), and others.
  - 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 both first and second generation CM control
  - Another formulation of spinosad, Entrust, is organically approved.
  - Up to three times as expensive as older chemistries
- ❖ Indoxacarb (Avaunt)
  - Small-plot and on-farm research conducted in MI 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 'reduced-risk' 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), and others
  - 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 MI 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
  - 2-3 times the 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 MI 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
  - 2-3 times more expensive than older chemistries.
- Imidacloprid (Provado)
  - A good insecticide for AM control.
  - However, not a good option for MI growers as it does not provides summer control of CM and OFM.
- Kaolin (Surround)
  - Shows promise in MI 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 MI 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.
    - Another formulation of spinosad, Entrust, is organically approved.
    - A bait spray formulation is registered (GF-120), but it is not effective under MI conditions of frequent precipitation and immigrating populations.
    - 2-3 times more expensive than older chemistries.
- ❖ 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; very costly and not as effective as above control measures.

Unregistered chemicals or other control materials

- ❖ Cyazypyr
    - Research trials indicate that this insecticide is effective for AM control.
    - Anticipated registration in 2013; Likely to be expensive.
- ❖ 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

- ❖ This is a highly critical use of Guthion, thus maintain registration of azinphos-methyl beyond its targeted withdrawal date of 2012
- ❖ 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), and others
  - Short residual, multiple applications required.
  - Alternative 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.
  - 2-3 times 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 MI 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
  - 2-3 times the cost of OP's.
- ❖ Acetamiprid (Assail)
  - An effective insecticide for PC control.
  - Best use of this compound for MI growers is for 2^{nd} 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 MI growers is for 2^{nd} generation control of CM and summer AM (One of several neonicotinoid insecticides used in apple IPM, thus resistance is a concern).
  - 2-3 times more expensive than older chemistries.
- ❖ Clothianodin (Clutch, Belay)

- An effective insecticide for PC control.
- Best use of this compound for MI 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).
- 2-3 times 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 MI.

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.

Unregistered chemicals or other control materials

❖ Entomopathogenic Nematodes (EAPN)
- Preliminary data in Michigan shows good efficacy.
- Attacks larval stage in soil upon leaving fruit.
- Research is continuing to optimize application in different soil types and irrigation regimes

❖ Fungus, Beauvaria bassiana (Bb)
- Preliminary research conducted in Michigan is promising
- . Target larval stage in soil upon leaving fruit
- Research is continuing to optimize application in different soil types and irrigation regimes

❖ Metaflumizone (Alverde®)
- Effectiveness for PC control unknown

Pest management aids

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

Strategies for future control ('To do' list)

Regulatory needs

❖ This is a critical use of Guthion., thus maintain registration of azinphos-methyl beyond its targeted withdrawal date of 2012

- 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), and others
  - 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
  - Reduced efficacy reported in WA; likely due to widespread reliance on this insecticide.
  - 2-3 times more expensive than older chemistries.
  - 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 MI growers as it also provides CM and OFM control.
    - Novel mode of action makes it a good resistance management option
    - 2-3 times 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 MI growers as it also provides CM and OFM control.
    - 2-3 times more expensive than older chemistries.
- ❖ Flubendiamide (Belt)
    - A highly effective insecticide for leafroller control.
    - Same mode of action as rynaxypyr, and thus a good resistance management option.
    - Up to three times as expensive as older chemistries.
- ❖ Novaluron (Rimon)
    - A highly effective insecticide for leafroller control. A good option for MI growers as it also provides CM and OFM control.
    - IGR with novel mode of action makes it a good resistance management option
    - 2-3 times 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
    - 2-3 times 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

- ❖ Cyazypyr
  - Research trials indicate efficacy against leafrollers.
  - Mode of action is the same as rynaxypyr, thus a good resistance management option.
  - Anticipated registration in 2013; 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 contol 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.
- ❖ Flonicamid (Beleaf)
  - Belongs to the pyrimidine carboxyamide class of insecticides
  - Provides excellent control of rosy apple aphid.
- ❖ 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 MI 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 MI 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, Belay)
- 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.

❖ Flonicamid (Beleaf)
- Belongs to the pyrimidine carboxyamide class of insecticides
- Provides excellent control of rosy apple aphid.

❖ Spirotetramat (Movento)
- Belongs to the tetramic acid derivatives class of insecticides
- Provides excellent control of rosy apple aphid.

Non-chemical options

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

Unregistered chemicals or other control materials

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. Wooly 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

- ❖ Spirotetromat (Movento)
    - Effective for WAA control; may require multiple applications.
- ❖ Endosulfan (Thiodan)
    - Effective, but will be phased out by 2015.
- ❖ 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.

❖ Thiacloprid (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.

❖ Spirotetramat (Movento)
- Belongs to the tetramic acid derivatives class of insecticides
- Provides good control of rosy apple aphid.

Non-chemical options

❖ Resistant rootstocks.

❖ Parasitoids.

Unregistered chemicals or other control materials

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.
- Spirotetromat (Movento)
    - Effective for WAA control; may require two applications.
- 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
- ❖ Flonicamid (Beleaf)

- Belongs to the pyrimidine carboxyamide class of insecticides
- Provides good control of tarnished plant bug.

❖ 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 3^{rd} to 4^{th} instars, and are therefore incapable of flight

Unregistered chemicals or other control materials

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, Belay)
  - 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 contol 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 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.

Management plans for apple diseases

The following is a pest-by-pest analysis of role of current fungicides, future disease control options, and the use of other pest management aids (cultural and otherwise), in Michigan apple production systems. 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.

- 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 MI 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

- **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.

- Resistance to strobilurin fungicides is widespread in Michigan.

❖ **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 russeting 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 russeting.

❖ **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 MI 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 partcularly 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 eradicant 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 (russeting) 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 russeting.
  - 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

- **Kasugamycin (Kasumin)**

  - Section 18 specific exemption for the use of kasugamycin was obtained in 2010 and 2011 for use in 8 MI counties (Berrien, Cass, Grand Traverse, Ionia, Kent, Montcalm, Oceana, Van Buren) impacted by streptomycin resistance.
  - 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 (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 controls will be important to maximize their effectiveness and to be able to predict their effectiveness in a given season.

- 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 russeting 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 *Phytophtora* 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

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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

Management of 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.
- Tilling under trees is being used to control weeds.
- Herbicide injuries to trees has increased.

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
- **Oxyfluorofen (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 and standard use 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

❖ **Glufolsinate (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 (conventional and organic).
- 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

Birds
Birds damage a significant but unquantified amount of apples each year. Damage includes pecked fruits and broken shoots. Injured fruit will rot.

Scare tactics

- Methods include balloons, noise-makers and decoy predator birds
- Not very effective

Research needs:

- Quantify damage and bird species responsible
- Identify landscape characteristics that might influence bird damage
- Test potential controls and expedite registration of new alternatives as they become available.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

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

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-coagulent, 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

Research needs:

- Develop and evaluate alternative management systems.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

- As technologies become available, educate users.

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

Research needs:

- Develop and evaluate alternative controls and strategies.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

- As technologies become available, educate users.

Plant Growth Regulators (PGR) and Post-Harvest Treatments

Apple PGRs
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.

- **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
  - Used as a stop-drop material
- **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 ¼ 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

❖ **Napthaleneacetimide (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 A_{4+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 Treatments

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, CO^2 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 and as a fog treatment in storage
  - Controls Storage Scald on some varieties
  - Controls CO^2 injury on Empire
  - Requires the addition of post-harvest fungicide to control rot

- **Thiabendazole (Mertec)**
    - Broad-spectrum fungicide applied as a post-harvest drench and as a fog treatment in storage
    - 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 repellant 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 MI 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 MI Apple industry is from closed cab sprayers with pesticide rated ventilation filtration systems
    - *Ca.* 50% of MI 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 MI 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, I 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 depend 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 1. Major Apple Production Activities Timetable

Major Apple Production Activities Timeline																																																
Month	January				February				March				April				May				June				July				August				September				October				November				December			
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	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Activity																																																
Dormant Pruning	■	■	■	■	■	■	■	■	■	■	■	■	■	■																													■	■	■	■	■	■
Removing Brush									■	■	■	■	■	■	■	■																																
Spraying, Pesticides, Plant Growth Regulators													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■															
Herbicides Application															■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■	■				
Scouting															■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
Planting																■	■	■	■	■	■																											
Irrigation Maintenance																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																
Mowing Orchards																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■														
Pollination with Bees																	■	■	■																													
Training trees																			■	■	■	■	■	■	■	■	■																					
Building Trellis																			■	■	■	■	■	■	■	■	■	■	■	■																		
Hand Thinning																						■	■	■	■	■	■	■																				
Summer pruning																								■	■	■	■	■	■	■	■	■																
Boxing Orchards & Harvest																															■	■	■	■	■	■	■	■	■	■	■							
Orchard Post-harvest activities																																								■	■	■	■					

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										■	■	■	■	■	■																	
ReTain																■	■	■	■													
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
Wooly 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 skelotonize 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 or 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

	Nematodes in Apple					
Management Tools	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	WiApplehgrass	Foxtail	Bindweed	Chickeweed	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

[1]Control 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.)**

	PERENNIAL WEEDS (CONT.)														
HERBICIDE	Mallow	Milkweed	Nightshade	Nutsedge	Quackgrass	Plantain	Poison Ivy	Sowthistle	Stinging Nettle	CaNapthaleneaceti midea Thistle	Velvetleaf	VeApplehes	Virginia Creeper	Horsenettle	Shephard'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

[1]Control 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.)

Ratings of control are **E = excellent, G = good, F = fair,** and **P = poor**.

Ratings against beneficials are **T = highly toxic, M = moderately toxic**, and **S = relatively safe**.

	Insect/Mite	Life Stage	Diazinon	Guthion	Imidan	Kelthane	Lannate	Malathion	Apollo	Provado	Sevin	Superior oil[1]	Thiodan	Vendex	Vydate	Lorsban[1]	Pounce	Ambush	Asana	Agri-Mek	Savey	B.T.'s ◄	Danitol	Nexter	SpinTor	Intrepid	Esteem	Surround ◄	Neem compounds ◄	Avaunt	Actara	Assail	Acramite	Calypso	Zeal	Entrust ◄	CM granulosis virus ◄	Warrior	GF 120 Fruit Fly Bait ◄	Kanemite	Decis	Clutch	Rimon	Baythroid	Envidor	Battalion	Portal	Proaxis	Proclaim	Centaur	Delegate	Mustang Max
			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		F		G	F		G			G		G		G			F	F
Pests	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	
Pests	Cutworms	Larva	P		F									E	E	E	E				E		G											G		E						E				E						E
Pests	European red mite	Active				F			E			E		E	G					E	E		G	E				F					G		E					G					E		E					
Pests	Green apple aphid	Active		P	P	P		G	P		E	P	P	F		G		F	F	F										G		E	E		E								E									
Pests	Green fruitworm	Larva	F	P	P		G						F		P	E	E	E	E			G	E		G	G	G									G		E			E		G	E		E		E	E		E	E
Pests	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
Pests	Oriental fruit moth	Larva	G	E	E		G				G								G				G		F	G	F			G				G		F		G			G		G	G		G		G	F/G		E	G
Pests	Plum curculio	Adult		E	E		F	P		F	F				P		G	G	G				G					F	P	E	G	E		E				G			G	E		G		G		G			F	G
Pests	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
Pests	Rose chafer	Adult								G	G								G				G					F	F	G	G	G		G				G			G			G		G		G				G
Pests	Rosy apple aphid	Active	P	P	P		G	P		E	P	E	E		G	E	F	F	F								G			G	E	E		E								E										
Pests	Rust mite	Active	P	P	P	F			F		G		E	G	F		P	P		G	F			E					G														G		E		E					
Pests	San Jose scale	Adult											E			E	P	P	P								E				F			G																		
Pests	San Jose scale	Crawler	G							F							P	P	P								G							F				E										E		G		
Pests	Spotted tentiform leafminer	Adult		P		F							F			P	E	E	E				E															E			E			E		E		E				E
Pests	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
Pests	Tarnished Plantbug	Active	P	P	P		G			G			F				E	E	E				E					G	G	G	G			G				E			E			E		E		E				E
Pests	Twospotted spider mite	Active						G	E					G	F					E	E		G	G									E		E					G					E		G		F			
Pests	White apple leafhopper	Active	P	P	P		E	P		E	E		F		E		P	P	G	G			G	F				G		F	E	E		E				G			G	E		G		G	F	G				G
Pests	Woolly apple aphid	Active	F				P			G	F		E		P	E	P	P											F		G																					
Beneficials	Bees		T	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	T	S	T	T
Beneficials	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	T	S	S	T	S	S	T	S	T	M	T	S	S	S	T
Beneficials	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	M	S	T	S	S	T	M	S	T	S	T	M	T	S	S	M	T

[1] Use only before pre-pink!

Table 8. Efficacy and control spectrum ratings for fungicides.

Class of fungicide/ Fungicide and rate per acre Classic Protectants	Scab	Powdery mildew	Sooty blotch & fly speck
Captan 50 W 6-8 lb	5	1	4
EBDC 6 lb (full rate)	5	1	*
EBDC 3 lb (half rate)	3	1	2**
Carbamate 76 W 6 lb	4	1	4
Ziram 76 DF 6-8 lb	3-4	1	3
Sulfur 95 W 9 lb	1	3-4	1
Sterol inhibitors/demethylation inhibitors plus protectant			
Indar 2F (6-8 oz) plus Captan 50 W (3-4 lb) or EBDC (3 lb)	5	5	3***
Procure 50 WS (8-16 oz) plus Captan 50 W (3-4 lb) or EBDC (3 Ib)	4-5	4	3***
Rally 40 W (5-8 oz) plus Captan 50 W (3-4 Ib) or EBDC (3 Ib)	5	5	3***
Rubigan 1 EC (9-12 oz) plus Captan 50 W (3-4 Ib) or EBDC (3 Ib)	5	5	3***
Strobilurins			
Flint 50 W 2-2.5 oz	6	4	4-5
Sovran 50 W 4-6.4 oz	6	4	4-5
Pristine 38 WG 10.5-14.7 oz	6	5-6	5
Anilinopyrimidines			
Vangard 75 WG 5 oz	4	1	*
Vangard 75 WG 3 oz plus a protectant 3-4 lb	4-5	1	*
Scala SC 10 oz	4-5	1	*
Scala SC 5 oz plus a protectant 3-4 lb	5	1	
Benzimidazoles			
Topsin M 70% WSB 8 oz plus Captan 50% WP 6 lb OR Ziram 76 DF 6 lb	R	5	5

After-infection or kickback action of apple fungicides.

Class of fungicide /Product Name	Rate/ acre	After inf. activity (hr)	Comments
Classic protectants			
Captan, EBDCs	full rates	18-24	No after-infection activity when used at half-rate.
Sterol inhibitors Rally 40 W Procure 50 WS Rubigan 1EC 1st spray 2nd spray	8 oz 12-16 oz 12 oz 8-12 oz	96 48-72 96	Less after-infection activity at reduced rates. After-infection control will be more difficult in orchards with SI-resistant strains.
Strobilurins Flint 50 W Sovran 50 W	2-2.5 oz 6.4 oz	48 48	Neither fungicide has provided adequate scab control when applied a few hours before the 96- to 100 hr after-infection times liste on labels. Assume about 48 hr of after-infection control until data are available. Repeat applications 7 days apart have not improved after-infection control.
Anilinopyrimidine			
Vangard 75 WG Scala SC	5 oz 7-10 oz	48 48	

6 = excellent, 5 = very good, 4 = good, 3 = fair, 2 = poor, 1 = none

R = significant resistance problems

* = not rated because of long interval between last application and harvest

** = overall effectiveness reduced because of 77-day PHI

*** = assumes Captan as mixing partner because of the long PHI for EBDC fungicides

Table 9. Toxicity of pesticides to mite and aphid predators

Material	Stethorus adults	Stethorus larvae	Amblyseius fallacis	General Zetzellia mali	Aphid-oletes	aphid predators
	Mite 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 10. Contacts and Contributors to 2000 PMSP Background Material

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

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