Tart Cherry
Pest Management in the Future: Development of a Strategic Plan

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Section I. Pest Management Priorities

Introduction

There are about 37,000 acres of red tart cherries nationwide, with Michigan accounting for nearly 27,300 acres and producing about 75% of the crop (NASS, 2005). Tart cherry 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, a tart cherry production system that relies on applications of broad-spectrum pesticides to control these pests has evolved. These materials have provided good control for over 35 years, but many factors acting together have heightened interest in alternative control tactics. Industry concerns about environmental quality, worker and food safety, pest resistance to pesticides, increasing production costs, potential loss of important pesticide tools, and the encroachment of urban areas on prime cherry production sites, have caused the cherry industry to carefully re-evaluate what had become the standard production system. Cherry 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. The tart cherry 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, regulatory, and consumer-driven pressures. The following research, regulatory, and education priorities were identified through the process.

Priorities for Tart Cherry Pest Management

Research

Insects

1. Develop and implement OP-alternative and Reduced Risk strategies for in-season control of PC & CFF at USDA mandated zero tolerance levels
    - a) IGR's, biopesticides, new insecticides not currently labeled for cherry
    - b) Improved monitoring and application timing protocols (phenology models)
    - c) Better understanding of resident vs. immigrant populations
    - d) CFF genetics – evolution of emergence later in season
2. Develop and implement OP-alternative and Reduced Risk strategies for Post Harvest control of PC & CFF (a-d, as above).
3. Develop and implement measures of orchard functional ecology
    - a) Impacts of management practices (orchard health/sustainability & natural enemy abundance and diversity)
    - b) Secure USEPA Re-registration of key pesticide tools
    - c) Improved knowledge of adjacent landscape effects on IPM
4. Develop monitoring and control strategies for secondary pests previously controlled by OP's (Leafrollers, Twospotted spider mites, Borers, Japanese beetle, Mineola moth)
5. Continued evaluation of breeding potential for genetic traits in tart cherry that could confer resistance to CFF and PC

Diseases

1. Develop and implement protocols for incorporating copper for cherry leaf spot control (rates, compatibility, phytotoxicity, lime rates, rotation strategies, and temperature constraints)
2. Investigate fungicides to replace carbamate and B2 fungicides and for rotation with copper, strobilurin, and boscalid fungicides.
3. Develop programs to reduce reliance on single-site fungicides and to delay the development of resistance.
4. Efficacy and economics of alternate row vs. full cover fungicide applications

5. Assess efficacy of strobilurin and boscalid fungicides for European brown rot.
6. Screen for strobilurin and boscalid resistance
7. Continued evaluation of breeding potential for genetic traits in tart cherry that could confer resistance to cherry leaf spot

Regulatory

1. Facilitate and engage the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacements and viable fungicides
   a) Only 2 insecticides registered since passage of FQPA
   b) Currently have only two traditional fungicides post bloom
2. Develop a system for evaluating new pesticides on farms before registration.
3. Ensure nursery stock is virus-tested for all known viruses.
4. Enforce laws regulating abandoned orchards and back-yard trees.
5. Increase cost sharing for implementation of IPM technologies (weather and others).

Education

- Expand information on new pest management advances for growers, consultants, and scouts.
- Improve delivery of real-time pest management information to the agricultural community.
- Offer apprenticeship programs for scout training.
- Educate consultants on options for additional income resources during off-season.
- Inform landowners about issues and laws regulating abandoned orchards and back-yard trees.
- Educate the general public about production agriculture.
- Provide hands-on educational opportunities for regulators and policymakers.

Development of a Tart Cherry Pest Management Strategic Plan

Background

- There are about 37,000 acres of red tart cherries nationwide, with Michigan accounting for *ca.* 27,300 acres and producing about 75% of the crop (NASS, 2005).
- In Michigan, the total farm value for both tart and sweet cherries is $ 40 to $60 million, depending on the size of the crop and price paid to growers.
- The value added by processing, manufacturing into other products, and marketing fresh product increases the farm value about three times to $120 to $180 million or more in Michigan alone (MASS, 2005).
- Other states with commercial crops of tart cherries include Utah, New York, Washington, Wisconsin and Pennsylvania.
- Select regions in western lower Michigan have particularly favorable soil and climatic conditions for growing cherries. Orchard soils are predominantly well drained, sandy loam to loamy sand, glacially deposited soils of low to moderate fertility. The climate is moderated by proximity to Lake Michigan, which results in long, frost-free autumns and a delayed spring bloom period.
- The major variety of tart cherry grown in Michigan is Montmorency, although minor acreage of Meteor and more recently, Balaton is grown.
- Nearly all red tart cherries are harvested with mechanical shakers. The cherries are harvested from the trees directly into large tanks containing 48ºF water. The fruit remains in the tanks for six to eight hours, while being constantly flushed with cold water. Flushing the cherries

with cold water helps cool the cherries quickly to help maintain fruit quality, washes the cherries, and helps minimize fruit bruising while en-route to the processing plant.
- It is critical that several key insect, disease, and weed pests be effectively controlled to maintain adequate yields of quality fruit that is acceptable to consumers.
- Tree growth and vigor, and fruit ripening must be managed to maintain the health and longevity of cherry orchards.
- Over time a tart cherry production system that relies on routine pesticide applications to control pests had evolved.
- Industry concerns about environmental quality, worker and food safety, pest resistance to pesticides, increasing production costs, potential loss of important pesticide tools, and the encroachment of urban area on prime cherry production sites, have caused the cherry industry to carefully re-evaluate what had become the standard production system.
- Cherry 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.

Important Pest Management Issues

Tart cherry insect pests are primarily controlled by broad-spectrum insecticides, such as organophosphorous compounds, while broad-spectrum fungicides are commonly used to control disease pests. These materials have provided good control for over 35 years, but many factors acting together have heightened interest in alternative control tactics. Pest resistance to insecticides, fungicides, and herbicides appears to be on the increase in some Michigan fruit growing areas. Broad-spectrum insecticides are toxic to natural enemies of some pests. Their use is a factor limiting the potential of biological control of certain pests in cherry orchards. New regulations governing pesticides, particularly the Food Quality Protection Act, and the public interest in reducing the use of pesticides will likely limit the availability of conventional insecticides, fungicides and herbicides in the future.

Historically, tart cherry 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 tart cherry 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 tart cherry industry continue to deliver the quality fruit demanded by the marketplace.

Justification and Possible Benefits to the Michigan Cherry Industry

A tart cherry 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 tart cherry 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 tart cherry 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 tart cherry 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 IGR's, and other more selective strategies and chemistries.

Summary of the Strategic Planning Process

- The overall goal of the pest management strategic planning process was 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 was to develop a document that will provide the foundation for a pest management strategic plan that will: a) effectively and economically address pest management issues that impact industry viability, and b) lessen dependency on organophosphate and carbamate insecticides and B2 fungicides in tart cherry production.*

- Work plan. The strategic planning process was initiated by the Michigan Cherry Committee (MCC) in December, 1999. The strategic planning document was developed in series of two workshops, using the following principles as an overall guide:

    1. Profitability for tart cherry growers will be the key element of the pest management strategic plan; cost-effective alternative pest management tools and programs are needed.
    2. Geographical regions will be considered when developing transition strategies due to differences in production practices, pest complex and pressure, and environmental conditions.
    3. A major outcome of the pest management strategic planning document will be to identify and prioritize research areas, regulatory actions, and educational programs required as tart cherry growers move away from FQPA-targeted pesticides.
    4. The completed pest management strategic plan will have the broad support of the Michigan tart cherry industry.

- An outline of the strategic planning document was completed at a workshop held at the Cherry Marketing Institute (CMI) conference room in DeWitt, Michigan on May 5, 2000 (see Appendix 5). The first draft of this document was based on a document developed by the MCC detailing the evolution of tart cherry IPM. A working draft was reviewed by the MCC, other growers, consultants, and processors for comment and approval.

- A larger workshop was held by the industry at the Northwest Michigan Horticultural Research Station on May 26, 2000 to review and revise the strategic planning document and to specifically develop the priorities list (page 4). By design, the research, regulatory, and educational needs as identified and prioritized in this document largely represent input by industry, growers, consultants, and processors, not the research and extension advisors to the workgroup. Wilfred Burr from the USDA facilitated the May 26 workshop.

- A Michigan workgroup consisting of tart cherry growers and technical experts then revised the working draft to incorporate review comments received during and subsequent to the May 26 workshop. This draft was circulated to all workshop participants for their comments and approval. The workgroup then completed the final Tart Cherry Pest Management Strategic Plan Document.

- A Michigan workgroup consisting of tart cherry growers and technical experts met in December 2006 to update the PMSP and to add a timeline detailing orchard activities throughout the year, and strategies undertaken to mitigate worker safety. This draft was circulated to all workshop participants for their comments and approval. The workgroup then completed the final Tart Cherry Pest Management Strategic Plan Update.

Section II. Outline of the Tart Cherry Pest Management Strategic Plan

Table 1. Cherry pests and disease problems in Michigan

Pests	Loss without control	Type of damage
Disease problems		
Cherry leaf spot	Severe	Leaf spots, defoliation, reduced fruit quality, weakening and loss of trees
Brown rot	Severe	Fruit decay
European brown rot	Rare, except in European cultivars	Killing of fruit spurs
Powdery mildew	Moderate	Distorted leaves, reduced shoot growth
Bacterial canker	Moderate to severe in sweet cherries	Spotting of leaves and fruit, spur die back, tree loss
Armillaria Root Rot	Severe	Kills trees and the site cannot be replanted to cherry
Phytophthora root rot	Minor	Kills root system causing tree die back and loss when orchards are planted on heavy soils
Nematodes		
Nematodes	Minor to severe in non-bearing. Minor in bearing.	Kills small roots, causes replant problems, and in some species vector viruses
Insect problems		
Plum curculio	Severe	Rejection of crop due to larval feeding in fruit at harvest; zero tolerance.
Cherry fruit fly and Black cherry fruit fly	Severe	Rejection of crop due to maggots in fruit at harvest, zero federal tolerance
Black cherry aphid	Minor	Twisting of leaves, stunted shoot growth
Mineola moth	Increasing concern with phase-out of azinphosmethyl, can be severe	Reduce fruit set; larva in fruit
Eye-spotted bud moth	Minor	Reduce fruit set
Scales	Minor	Weakening of trees (reduced vigor)
Green fruitworm	Moderate	Feeding on young fruit
American plum borer, Peach tree borer, and Lesser peach tree borer	Increasing concern with restrictions on use of chlorpyrifos, moderate	Girdling of branches and trunk, killing of branches and trees
European red mite, Two-spotted spider mite, and Plum nursery mite	Moderate to major	Bronzing or browning or leaves, defoliation, branch die back
Oblique banded leafroller	Minor	Feeds on leaves and fruit
White grubs and Japanese beetles	Minor, but serious problems do occur, has extended its geographical range throughout MI	Damages roots, reduces growth of new trees

FOUNDATION OF STRATEGIC PLAN

- ♦ This section of this document is a pest by pest analysis of the current role of organophosphates, (OPs), carbamates and pesticides classified as B2 carcinogens, the use of other pest management aids (chemical, cultural and otherwise), and pipeline pest management tools.

Insects of Tart Cherry

1. Cherry Fruit Fly (*Rhagoletis cingulata and Rhagoletis fausta*)

- One of the two most common internal feeders on tart cherries.
- There is a zero tolerance for cherry fruit fly, mandated by state and federal law and by the market place.
- Truckload quantities and even entire blocks of fruit may be rejected if any larvae from fruit fly are found.
- Some cherry processors have informed growers that costs associated with product rejection due to worms found in processed product will be billed back to the growers.
- Population densities of CFF have increased on tart cherry farms across MI since PMSP written in 2001, resulting in increased numbers of rejected loads; un-harvested cherries left in the orchard due to set aside requirements are suspected of contributing to the increase.
- Infested fruit is more susceptible to brown rot and other diseases, so fungicides used to control these diseases in the orchard are increased.
- Primarily a late season pest close to harvest. Control absolutely necessary at or near harvest time, necessitating short REI and PHI for incorporation into IPM program.
- Extending REI's and PHI's of OP's and carbamates would have a negative impact and necessitate a switch reliance to less effective chemistries, which could upset current IPM programs.
- Imidan (phosmet) use is increasing as a CFF control due largely to 7 day PHI enabling use closer to harvest
- CFF OP alternative insecticides introduced since 1996 increase the risk to growers of CFF larvae in fruit at harvest; *ca.* 1% of industry has adopted use of OP alternative chemistries
- Wild cherry trees are alternate hosts, and there is a state law for removal of abandoned cherry orchards.
- There is one generation per season.
- Note: Worker re-entry is important for harvest; if it exceeds PHI it may be difficult for harvest and personal protective equipment is simply untenable.
- Post harvest sprays could be beneficial, but more research is needed to confirm the efficacy of this strategy.

Scale used to rate effectiveness of materials listed, below:

Poor ---------- Fair ----------- Good ----------Excellent →

Organophosphates

- **Azinphos-methyl (Guthion)**

- Most widely used insecticide for control of cherry fruit fly (94% of crop treated).
- USEPA phase-out of AZM by 2012
- Current 15-day REI and PHI, inhibits control close to harvest when pest most active
- Excellent and best control.
- Soft on predator mites.

- **Phosmet (Imidan)**
  - >50% of crop treated in Michigan.
  - Sister product to Guthion, second most widely used.
  - Excellent control, but shorter residual effect than Guthion.
  - Soft on predator mites.
  - 7-day PHI; reason for increase in use.
- **Imidicloprid (Provado)**
  - Good control
  - Requires ingestion
  - 7 – 10 day residual activity
  - 7-day PHI, 12 hour REI
- **Diazinon**
  - Not used.
- **Malathion**
  - If ULV formulation is applied it works well, ULV formulation not used because it is usually applied by aerial application and aerial application are rarely used in cherry orchards.

Carbamates

- **Carbaryl (Sevin)**
  - Effective control but short residual, requires more frequent sprays.
  - Disruptive to beneficial mites and established IPM programs.

Other insecticides currently registered:

- **Permethrin (Ambush, Pounce)**
  - Control is fair, does not provide effective control to meet zero tolerance requirements.
  - Short residual.
  - Disruptive to beneficial mites and established IPM programs.
- **Esfenvalerate (Asana)**
  - Control is poor to fair, does not provide effective control to meet zero tolerance requirements.
  - Disruptive to beneficial mites and established IPM programs.
  - Currently not used for cherry fruit fly.
- **Thiamethoxam (Actara)**
  - Good control
  - 14 day PHI, inhibits control close to harvest when pest most active
  - Toxic to wildlife and highly toxic to aquatic invertebrates and bees
  - Limited to 1 application per season at recommended rate of 4.5-5.5 oz./ac, Maximum use of 8.0 oz. per season
- **Spinosad (Spintor, Entrust, GF120 NF)**
  - Good control, requires ingestion to be lethal, not fast acting.
  - 7-14 day residual control, 7 day PHI.
  - Prohibitively expensive.

- Entrust registered for use in organic production, 7-10 day residual control
- GF120NF provides fair control, bait formulation, registered for use in organic production

- **Dimethoate**
  - No label east of the Mississippi.
- **Kaolin (Surround)**
  - Good control
  - Not used in most Great Lakes region orchards.
  - Requires many applications.
  - Maintaining coverage is difficult with rainfall.
  - Expensive
  - There are questions about how processors will remove residue.

PIPELINE

- **Entomopathogenic Nematodes (EPN)**
  - No research conducted in Michigan to date
  - Preliminary data in WA shows EPN to be effective predators
  - Attacks larval stage in soil upon leaving fruit
  - Does not prevent immigrant gravid female flies from flying into the orchard and laying eggs
- **Calypso**
  - Preliminary data from in CFF trials are promising with good fruit protection, but requires ingestion for optimal performance
  - 30 day PHI in apple, concern for control close to harvest when pest most active
- ***Beauvaria bassiana (Bb)***
  - No research conducted in Michigan to date on control of CFF
- **Rynaxypyr (Altacor)**
  - Effectiveness for CFF control unknown, IR4 trials in MI in 2007
  - Expected EPA registration 2009
- **Flubendiamide (Belt)**
  - Effectiveness for CFF control unknown
  - EPA registration 2009 (?)
- **Spinetoram (Delegate)**
  - Stronger activity on CFF reported
  - Broad-spectrum activity
  - EPA may allow bridging data with SpinTor for fast track registration 2009(?)
- **Metaflumizone** (Alverde)
  - Effectiveness for CFF control unknown
- **Pesticide-treated Biodegradable spheres**
  - Attract and kill tactic
  - Preliminary data in apple indicates fair control
  - Potential use to reduce number of sprays
- **Neemix**
  - Unknown; apple maggot data indicates poor to fair effectiveness

Pest Management Aids (Not stand alone)

- Orchard monitoring program that has already significantly reduced organophosphate applications.

- Border row spraying rather than entire orchards.
- Alternate row spraying is now the standard method of application.
- No effective biological control.
- Harvest as much fruit as possible to reduce fruit fly in the orchard. Use of ethephon as a loosener to help harvest a high percentage of the fruit.
- Remove alternate hosts, including abandoned orchards

"To do" list for cherry fruit fly:
Research needs:
- Test new insecticides to find alternatives to organophosphate and carbamate insecticides.
- Evaluate and develop post-harvest control strategies (currently labeled materials, IGR's, new insecticides not currently labeled for cherry)
- Improved trapping/monitoring systems and pest phenology model.
- Management of CFF populations in landscapes adjacent to orchards.
- Spinosad/bait (bait and kill)
- Evaluate the potential for biological control to aid in population reduction, particularly during pupal stage in soil (EPN and *Bb*).
- Evaluate new 'pest management systems' that are innovative, multidisciplinary, and incorporate new strategies, tactics, and chemistries to reduce reliance on pesticides at risk.
- Continue to evaluate spray application strategies designed to reduce pesticide use.
- Explore visioning and technology for detection of larvae in fruit during processing.

Regulatory needs:
- Facilitate and engage the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacements.

Education needs:
- As products and/or insect management strategies become available, educate users and crop consultants.

2. Plum Curculio *(Conotrachelus nenuphar)*

- The plum curculio is one of the most prominent insects attacking tree fruits, and population densities have steadily increased on farms across the state over the past four years.
- Un-harvested cherries left in the orchard due to set aside requirements are suspected of contributing to the increase in PC populations
- Plum curculio is considered a difficult pest to monitor and control.
- Plum curculio larvae may remain in cherry fruit at harvest.
- There is a zero tolerance for larvae or "worms" in fruit as mandated by state and federal law and by the market place.
- Truck-load quantities and even entire blocks of fruit may be rejected if larvae from curculio are found.
- Some cherry processors have informed growers that costs associated with product rejection due to worms found in processed product will be billed back to the growers
- Only one new insecticide has been labeled for PC since 2001
- There is one generation per season.
- There are no commercially available pheromones for monitoring or controlling this insect
- Winter hibernation areas include woodlots, fences, or ditches; and possibly in orchards.

Organophosphates

- **Azinphos-methyl (Guthion)**
  - Most widely used insecticide for control of plum curculio (94% of crop treated).
  - Excellent and best control, with curative effects causing larval mortality in fruit
  - Good IPM product that is soft on predator mites
  - USEPA has issued a time schedule to phase-out AZM use by 2012
- **Phosmet (Imidan)**
  - Sister product to Guthion, second most widely used.
  - Good control, but no curative effects causing larval mortality in fruit
  - Soft on predator mites
- **Diazinon**
  - Not used, less effective.
- **Malathion**
  - Effectiveness is poor, therefore malathion is not used.

Carbamates

- **Carbaryl (Sevin)**
  - Control is fair, not effective enough to meet zero tolerance.
  - Disruptive to mites

Other insecticides currently registered:

- **Thiamethoxam (Actara)**
  - Preliminary data in Michigan shows some efficacy on PC
  - label limits application to 8 oz/season, effectively limiting growers to one application of this material at the recommended rate of 4.6 oz/ac.
- **Permethrin (Ambush, Pounce)**
  - Control is good if used at high rate, not effective at reduced rates or alternate row.
  - Short residual, requires more frequent application.
  - Disruptive to predator mites
- **Esfenvalerate (Asana)**
  - Control is good if used at high rate, not effective at reduced rates or alternate row.
  - Short residual
  - Disruptive to predator mites
- **Kaolin (Surround)**
  - Fair control, insufficient efficacy with zero tolerance standard.
  - Maintaining coverage is difficult with rainfall during critical times to control plum curculio
- **Neemix**
  - Poor control
  - Neem compounds have very short residuals and are not rainfast

PIPELINE

- **Entomopathogenic Nematodes (EPN)**
  - Preliminary data in Michigan shows good efficacy
  - Attacks larval stage in soil upon leaving fruit
- **Avaunt**
  - EUP issued for use on 9 farms in MI, 2004-2007

- Preliminary results are positive
- ***Beauvaria bassiana (Bb)***
- - Preliminary research conducted in Michigan is promising
- **Calypso**
  - Efficacy tests in MI in 2007
- **Spinetoram (Delegate)**
  - Broad-spectrum activity
  - EPA may allow bridging data with SpinTor for fast track registration 2009(?)
- **Metaflumizone** (Alverde)
  - Effectiveness for PC control unknown

Pest Management Aids (Not stand alone)
- Developed monitoring program that has significantly reduced organophosphate applications.
- Border row spraying rather than entire orchards.
- Alternate row spraying is standard method of application, when using azinphos-methyl or phosmet. Other insecticides applied every row.
- Harvest as much fruit as possible. Use of ethephon as loosener to help harvest a high percentage of the fruit.
- Remove alternate hosts including abandoned orchards

"To do" list for plum curculio:
Research needs:
- Develop and implement OP-alternative (IGR's, biopesticides, new insecticides not currently labeled for cherry) and Reduced Risk strategies for in-season control of PC at USDA mandated zero tolerance levels
- Evaluate and develop post-harvest control strategies (currently labeled materials, IGR's, new insecticides not currently labeled for cherry)
- Improved monitoring and application timing protocols (phenology models);.
- Develop a better understanding of resident vs. immigrant populations; management of PC populations in landscapes adjacent to orchards.
- Evaluate new pest management strategies, including trap out and bait and kill.
- Identify attractants and repellents for possible use in PC management.
- Establish and assess new 'pest management systems' that are innovative, multidisciplinary, and incorporate new strategies, tactics, and chemistries to reduce reliance on pesticides at risk.
- Evaluate potential for biological control of plum curculio. Potential biological controls include EPN, *Bb,* Bacillus, Entomophagous fly.
- Continue to evaluate spray application strategies designed to reduce pesticide use.
- Explore alternative processing techniques and visioning technology to reduce and/or detect PC larvae.

Regulatory needs:
- Facilitate and engage the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacements
- Better enforcement of abandoned orchard removal regulations

Education needs:
- As products and/or insect management strategies become available, educate users.

3. American Plum Borer *(Euzohera semifuneralis)*

- American plum borer has become a major pest of commercial cherry orchards (unique to Great Lakes region).
- The principal damage is done by the larvae, which feed on the cambium, or growing tissue, and inner bark of the tree.
- Larval feeding may completely girdle and kill trees.
- Borer damage predisposes trees to damage by other insects, diseases and environmental stresses.
- The American plum borer is often found in close association with the lesser peachtree borer beneath the bark of wounded cherry trees
- Mechanical harvesting of cherries has been responsible for this insect changing from a minor to a major pest of cherries
- The highest infestations occur in older orchards that have experienced several years of wounding, especially where mechanical harvesting damage is present.
- Trunk sprays of chlopyriphos are effective; trunk sprays result in minimal contact with fruit.
- Increasing grower concerns with loss of Lorsban (chlorpyrifos) for trunk sprays to control borers

Organophosphates

- **Chlorpyrifos (Lorsban 4E)**
  - Applied with a hydraulic gun to the trunk at the petal fall stage when the first generation adults are emerging on tart cherries.
  - Most effective material available
- **Endosulfan (Thiodan)**
  - Applied as above
  - Less effective than chlorpyrifos; multiple applications required.

Other insecticides currently registered:

- **Permethrin (Ambush, Pounce)**
  - Not used for borer – requires multiple application
  - Control is only fair.
  - Short residual
- **Esfenvalerate (Asana)**
  - Not used for borer – requires multiple application
  - Control is only fair
- **Spinosad (Spintor)**
  - Has not been used yet in Michigan orchards.
  - Potential for borer is unknown

PIPELINE

- **Entomopathogenic Nematodes (EPN)**
  - Unknown
- **Actara and Calypso**
  - Unknown.
- **Rynaxypyr (Alticor)**
  - Unknown
- **Flubendiamide (Belt)**

- Unknown
- **Metaflumizone**
  - Unknown
- **Spinetoram (Delegate)**
  - Unknown
- **Avaunt**
- - Not effective
- **Neemix**
  - Doubtful for control possibilities

Pest Management Aids (Not stand alone)
- Newer mechanical shaker designs help minimize trunk injury
- No known effective biological control.

"To do" list for American plum borer:
Research needs:
- Priority need for research into Lorsban alternatives for trunk spray applications and evaluate their relative importance for Michigan tart cherry orchards
- Evaluate new pest management strategies, such as pheromone disruption.
- Establish and assess new 'pest management systems' that are innovative, multidisciplinary, and incorporate new strategies, tactics, and chemistries to reduce reliance on pesticides at risk.
- Develop application technology with visioning capability to target application to the tree trunks, eliminating the need for hydraulic gun application.

Regulatory needs:
- Facilitate and engage the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacements

Education needs:
- Educate users as products and/or insect management strategies become available.

4. Peachtree Borer (*Synanthedon exitiosa* (Say)) & Lesser Peachtree Borer (*S. pictipes* (Grote & Robinson))

- The principal damage is done by the larvae, which feed on the cambium, or growing tissue, and inner bark of the tree.
- Larval feeding may completely girdle and kill trees.
- Borer damage predisposes trees to damage by other insects, diseases and environmental stresses.
- Mechanical harvesting of cherries has been responsible for this insect changing from a minor to a significant pest of cherries
- The highest infestations occur in older orchards that have experienced several years of wounding, especially where mechanical harvesting is used.
- Trunk sprays of chlopyriphos are effective; trunk sprays result in minimal contact with fruit.
- Increasing grower concerns with loss of chlorpyrifos for trunk sprays to control borers
- Pheromone disruption shows some promise as an alternative.

Organophosphates

- **Chlopyrifos (Lorsban 4E)**
  - applied with a hydraulic gun to the trunk from the petal fall stage to three weeks after petal fall, when the first generation larvae are hatching.
- **Endosulfan (Thiodan)**
  - Applied as above.
  - Not as effective as chlorpyrifos, therefore no longer used.

Other insecticides currently registered:

- **Permethrin (Ambush, Pounce)**
  - Not used for borer.
  - Not effective.
  - Short residual.
- **Esfenvalerate (Asana)**
  - Not used for borer.
  - Control is only fair.
  - Short residual.

PIPELINE

- **Actara and Calypso**
  - Unknown, but being tested for dogwood borer in apple.
- **Entomopathogenic Nematodes (EPN)**
  - Unknown
- **Actara and Calypso**
  - Unknown.
- **Rynaxypyr (Alticor)**
  - Unknown
- **Flubendiamide (Belt)**
  - Unknown
- **Metaflumizone**
  - Unknown
- **Spinetoram (Delegate)**
  - Unknown

Pest Management Aids (Not stand alone)

- Newer mechanical shaker designs help minimize trunk injury.
- No known effective biological control.

"To do" list for peachtree borer and lesser peachtree borer:
Research needs:

- Priority need for research into Lorsban alternatives for trunk spray applications and evaluate their relative importance for Michigan tart cherry orchards
- Pheromone disruption to reduce populations and injury
- Test new alternative chemistries for borer management and evaluate their relative importance for Michigan tart cherry orchards.
- Establish and assess new 'pest management systems' that are innovative, multidisciplinary, and incorporate new strategies, tactics, and chemistries to reduce reliance on pesticides at risk.

- Trunk application research for all borers.

Regulatory needs:
- Facilitate and engage the IR-4 Pesticide Clearance Report (PCR) process to accelerate registration of candidate OP replacements.

Education needs:
- Educate users as products and/or insect management strategies become available.

5. Green Fruit Worms: *speckled green fruitworm* (*Orthosia hibisci (Guenee)), is the primary species that causes damage in cherry; yellow-striped fruitworm (Lithophane unimoda (Lentner)),; pyramidal fruitworm (Amphepyria pyramidoides (Guenee))*

- Can cause significant damage to cherry.
- Problem is regional within Michigan.
- Feeds on blossoms and young fruit.

Organophosphates
- **Azinphos-methyl (Guthion)**
  - Does not provide effective control.
  - Soft on predator mites.
- **Phosmet (Imidan)**
  - Sister product to Guthion.
  - Does not provide effective control.
  - Soft on predator mites.
- **Chlorpyriphos (Lorsban)**
  -Provides excellent control.
  -Soft on beneficial mites.
  -Limited to pre-bloom use.
- **Diazinon**
  - Not used, not effective.
  - Expensive.

Other insecticides currently registered:
- **Pyrethroids: Permethrin (Ambush, Pounce) and Lamda cyhalothrin (Warrior)**
  - Control is excellent
  - Short residual
  - Disruptive to predator mites
- **Esfenvalerate (Asana)**
  - Control is excellent
  - Disruptive to predator mites
- **Endosulfan (Thiodan)**
  - Fair control
- **Bt**
  - Control is fair – multiple applications may be needed.
  -Bt is most effective when applied to early instars, timing is critical.
  -Bt is less effective in cool seasons (i.e. temperature dependent).

- Can be applied during bloom.
- Soft on predators.
- Does not control plum curculio which may also be present at same time.

- **Thiamethoxam (Actara)**
  - Excellent control
  - High product cost
- **Spinosad (Spintor, Entrust)**
  - Excellent control
  - High product cost
- **Intrepid**
  - Excellent control
  - High product cost
- **Pyriproxifen (Esteem)**
  -Good control
  - High product cost
- **Kaolin (Surround)**
  - Just registered, not used yet in Michigan orchards.
  - Effectiveness unknown, but not likely.

PIPELINE

- **Pheromone products**
  - may show some potential.
- **Rynaxypyr (Alticor)**
  - Unknown
- **Flubendiamide (Belt)**
  - Unknown
- **Metaflumizone**
  - Unknown
- **Spinetoram (Delegate)**
  - Unknown
- **Neemix**
  - Unknown.
- **Calypso**
  - Potential for effectiveness.
- **Avaunt**
  -Potential for effectiveness.

Pest Management Aids (Not stand alone)

- Orchard monitoring program has already significantly reduced insecticide applications.
- No known effective biological control.

"To do" list for green fruit worm:
Research needs:

- Develop cost effective management with new insecticides
- Evaluate the relative importance of new pipeline chemistries for green fruit worm. management for Michigan tart cherry orchards.
- Evaluate new pest management strategies such as pheromone disruption.
- Research needed on biological control.

- Establish and assess new ‘pest management systems’ that are innovative, multidisciplinary, and incorporate new strategies, tactics, and chemistries to reduce reliance on pesticides at risk.

Regulatory needs:
- Expedite registration of new alternatives as they become available.

Education needs:
- As products and/or insect management strategies become available, educate users.

6. Two Spotted Spider Mites (Tetranychus Urticae) & European Red Mites (Panonychus Ulmi)

- Reduction in tree photosynthesis, winter hardiness, and return bloom can result from high infestations.
- Generally feed on leaves; but occasionally feed on fruit, making the fruit unmarketable.
- Conservation of predator mites important for biological control.
- Groundcover/habitat management plays an important role.
- When used for the control of other insects, Organophosphates have little impact on predator mites.

Organophosphates
- Not used for mite control.

Other miticides currently registered:

Currently registered products are all important for resistance management.
- **Fenbutatin Oxide (Vendex)**
  - Control is good for both ERM & 2-spotted.
  - Soft on predator mites.
- **Clofentezine (Apollo)**
  - Control is excellent for both ERM & 2-spotted.
  - Good product to aid in establishing biological control.
- **Pyridaben (Pyramite, Nexter)**
  -Control is excellent for ERM, good for 2-spotted.
- **Spirodiclofen (Envidor)**
  -Excellent control of ERM and 2-spotted
- **Superior oil**
  - Excellent control of ERM, only
- **Hexythiazox (Savey)**
  - Control is excellent for both ERM & 2-spotted
- **Bifenazate (Acramite)**
  - Good control of ERM, excellent control of 2-spotted
- **Kaolin Clay (Surround)**
  - Fair control of ERM, only

PIPELINE
- **Agrimek**
  - effective product, but not labeled.

Pest Management Aids (Not stand alone)

- Orchard monitoring reduces miticide applications by determining if and when miticides are required.
- Effective biological control through conservation of predator mites.
- Groundcover/habitat management plays an important role.
- Organophosphates have little impact on predator mites.

"To do" list for mites:
Research needs:

- Continued evaluation of orchard floor, pest and nutritional management strategies to improve conservation of predator mites.
- Assess new miticides, particularly impact on predator mites.
- Assess impact of other new insecticides and fungicides on pest and beneficial mites.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

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

7. Other Insect Pests:

When changes in pesticide products, strategies, and tools used for insect management in tart cherries occur, then other pests currently considered as minor, may become more serious problems.

- **Japanese Beetle (JB):**
    - Adults feed in groups & skelotonize leaf tissue & sometimes fruit
    - JB has extended its geographical range throughout MI
    - Difficult to control without contact efficacy of OP's
- **Mineola Moth (MM):**
    - Overwintering larvae feed on fruit buds and developing flower parts in early spring, web together developing leaf clusters and flower petals to form nests
    - Larvae of next generation feed inside the fruit
    - Grower community concerned with potential increase in MM population densities; development of a reliable monitoring system desired
- **Sap Beetles (SB):**
    - Population densities of SB have increased on tart cherry farms participating in USDA funded RAMP project investigating use of OP alternatives for insect control (2003-2007)
    - Larvae feed inside of fruit
    - Grower community concerned with potential increase in SB population densities; development of a reliable monitoring system desired

Diseases of Tart Cherry

Major Disease Problems

- American brown rot and cherry leaf spot must be controlled annually and are listed first.
- A range of other fruit and foliage disease problems are occasionally important. A few of these diseases are controlled by adding a second fungicide to a brown rot and/or leaf spot fungicide.
- Pesticides are also used in part to control bacterial, viral, and soil-borne fungal pathogens of cherry.

1. American brown rot (*Monilinia fructicola*)

- Fruit rot control is critical because truck load quantities, even entire blocks of fruit, can be rejected due to brown rot. Highly effective brown rot fungicides are essential for tart cherry production, particularly close to harvest.

- Some fungicides are only labeled for use during bloom to control blossom blight.
- Brown rot on unharvested fruit (particularly on un-harvested blocks) maintains disease at high levels.

Carbamate and B2 carcinogenic fungicides currently registered:

-

- **Chlorothalonil (Bravo)**
  - Widely used for early season leaf spot control.
  - Controls brown rot blossom blight, too.
  - Can't be used past shuck split.
- **Captan (Captan)**
  - Widely used as tankmix with SI fungicides for brown rot control.
- **Iprodione (Rovral)**
  - Very expensive.
  - Provides excellent brown rot control, but only bloom applications are currently permitted.
  - Recent loss of pre-harvest label will result in more rapid development of resistance to SI fungicides.

*Loss of these products in particular would increase reliance on SI fungicides, increasing resistance problems.

Other fungicides currently registered:

♦ *Sterol Inhibitor Fungicides*
- fenarimol (Rubigan)
- fenbucanazole (Indar)
- myclobutanil (Nova)
- propiconazole (Orbit)
- tebuconazole (Elite)

(all except fenarimol are excellent for brown rot blossom blight and all except fenarimol and myclobutanil are excellent for fruit brown rot.)

♦ *Non-Sterol Inhibitor Fungicides*
- cyprodinil (Vangard) - can only be used during bloom; less-effective than SI fungicides.thiophanate-methyl (Topsin-M) significant resistance problems.

♦ ***Strobilurin Fungicides***

- **trifloxystrobin (Gem)**
  - Reduced risk fungicide has good efficacy.
- **trifloxystrobin-boscalid (Pristine)**
  - This fungicide mixture has good efficacy.

♦ *In-Organic Fungicides*

- Lime sulfur, sulfur, and coppers
  - Often phytotoxic and less efficacious than organic fungicides.
  - Weak.
  - Relatively inexpensive.
  - hydrated lime is added as a safener for Cu; causes problems with alkaline hydrolyzed breakdown of tan- mixed insecticides

Other pest management aids:

- None.
- Value of sanitation has not been established.
- Host resistance is not a significant factor.

PIPELINE

"To do" list for brown rot:
Research needs:

- Test new fungicides to find alternatives to carbamate and B2 fungicides and for delaying resistance to SI fungicides.
- Establish the effectiveness of full rate strobilurin and SI product mixtures
- Identify sources of primary and secondary inoculum; assess their relative importance for Michigan tart cherry orchards.
- Closer monitoring of weather data if models were developed.
- Establish the importance of bloom sprays to overall brown rot control.
- Establish if brown rot control failures in well-sprayed orchards are due to SI-resistant strains.
- Establish the effect of wounding, inoculum density, and fruit-to-fruit contact on brown rot severity.
- Establish if sanitation effectively reduces disease and is cost effective.
- Develop temperature/leaf wetness/humidity based model for predicting infection of blossoms and a second model for fruit.
- Develop an inoculum-based model for timing fungicide sprays.
- Evaluate if latent or quiescent infections of young fruits are important. Previous work shows importance in semi-aired regions like Australia and California.

Regulatory needs:

- Expedite registration of new alternatives as they become available.

Education needs:

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

2. Cherry leaf spot (*Blumeriella jaapii*)

Requires control every season. Fungicide applications to control cherry leaf spot are applied at petal fall and repeated at 7- to 10-day intervals to harvest, plus one or two postharvest applications. With the loss of captafol (Difolatan) in the mid-1980's this timing is barely adequate for acceptable control.

Impending fungicide resistance to SI fungicides could jeopardize the reductions in fungicide use already made in cherry orchards.

Lack of control results in leaf loss in mid-summer, leading to significant loss of fruit quality and yield. Fruit is not marketable when severe defoliation occurs early in the season. Tree death can result when leaf spot causes early defoliation prior to a cold winter. In that case trees fail to develop the necessary winter hardiness to survive a cold winter.

Carbamate and B2 carcinogenic fungicides currently registered*:

- **Captan**
  - Widely used tank mixed with SI fungicides for resistance management and improved leaf spot control.
- **Chlorothalonil (Bravo)**
  - Although expensive, the standard for early season and postharvest leaf spot control.
  - Extremely important for resistance management, leaf spot would be much more - difficult to control without this fungicide.
  - Use limited to early season (pre-shuck-split) and post-harvest.

*Loss of these products would increase reliance on strobilurin and other single-site fungicides, increasing resistance problems and making this disease more difficult to control.

Other fungicides currently registered:

- **Copper fungicides** - various formulations
  - Provide excellent leaf spot control
  - hydrated lime is added as a safener for Cu; causes problems with alkaline hydrolyzed breakdown of tan- mixed insecticides
  - Copper can be phytotoxic to tart cherry trees causing foliage damage and defoliation
- **Strobilurin fungicides** - trifloxystrobin (Gem)
  - Provide excellent leaf spot control
  - Single site fungicide is at risk for resistance development
- **Strobilurin plus boscalid fungicide** (Pristine)
  - Provides excellent leaf spot control
  - The strobilurin fungicide in Pristine only provides weak leaf spot efficacy. The boscalid component is a single site fungicide which is at risk for resistance development
- **SI fungicides** - fenbuconazole (Indar), myclobutanil (Nova), tebuconazole (Elite), fenarimol (Rubigan)
  - Widespread resistance to SI fungicides is currently prevalent in Michigan. Limited control can still be achieved in orchards using a tankmix of an SI plus Captan.
- **dodine (Syllit)**
  - Used to be the standard leaf spot fungicide
  - Due to resistance, usually not used more than once or twice per season

  - A tank mix of dodine plus Captan is recommended due to resistance considerations
- **sulfur**
  - Very weak
  - Sometime added at reduced rates for powdery mildew control.

- **ferbam (Carbamate)**
  - Weak
  - Poor control most years
- **ziram (Ziram)**
  - Weak
  - Poor control most years

Other pest management aids:
- Alternate-row-middle spraying for leaf spot has resulted in a 20% reduction in fungicide use.
- Wetness/temperature disease forecasting system used to time fungicide sprays.

PIPELINE
-

"To do" list for cherry leaf spot:
Research needs:
- Need reduced risk fungicides to replace carbamate and B2 fungicides and for rotation with copper, strobilurin, and boscalid fungicides.
- Develop programs to reduce reliance on single-site fungicides and to delay the development of resistance.
- Develop field guidelines for copper use to eliminate risks of phytotoxicity and to increase adoption by growers.
- Check on adverse effects of Cu in orchard environment, ie, decreased soil microbe activity.
- Screen cherry germplasm for sources of resistance and breed for leaf spot resistance.

Regulatory needs:
- Expedite registration of new alternatives as they become available.

Educution needs:
- As products and /or disease management strategies become available, educate users.

Other Disease Problems of Tart Cherry

- Most of these diseases require control measures in addition to those for brown rot and leaf spot.
- The importance of the following diseases varies from minor to significant industry-wide problems. For example, Armillaria root rot is destroying some of Michigan's best orchard sites. Virus diseases are eventually a problem in all orchards; they debilitate trees over time.

3. Powdery mildew (*Podosphaera clandestina*)

- Disrupts mechanical harvesting; reduces growth of young trees. Unlike brown rot and leaf spot, a problem in dry years.
- Mildew will increase as a problem when SI usage is reduced for leafspot control.

Fungicides currently registered:
- **trifloxystrobin (Gem)**
- **pyraclostrobin and boscalid (Pristine)**
- **copper compounds**
- **myclobutanil (Nova)**
- **fenbuconazole (Indar)**
- **tebuconazole (Elite)**
- **propiconazole (Orbit)**
- **fenarimol (Rubigan)**
- **sulfur**

Other pest management aids:
- None

Pipeline pest management tools:
- None

"To do" list for powdery mildew:
Research needs:
- Screen powdery mildew isolates for the development of SI resistance.
- Establish economic thresholds for mildew control, particularly for young trees.
- Screen cherry germplasm for sources of resistance and breed for mildew resistance.

Regulatory needs:
- Expedite registration of new alternatives as they become available.

Education needs:
- None

4. Black knot (*Apiosporina morbosa*)
- Not currently a problem in Michigan cherry orchards, but a significant problem on tart cherries in New York and Ontario, Canada.

B2 carcinogenic fungicides currently registered:
- **Chlorothalonil (Bravo)**
  - The most effective fungicide for control.

Other fungicides currently registered:
- None
- SI's not effective.

Other pest management aids:
- Scouting for knots.

- Removing and destroying infected limbs on trees in the orchard and in adjacent fence rows or in neighboring plum orchards.

PIPELINE
- None in Michigan until disease becomes established.

"To do" list for black knot:
Research needs:
- None in Michigan until the disease becomes established.

Regulatory needs:
- Maintain the current registration for chlorothalonil (Bravo).
- Loss of chlorothalonil (Bravo) on cherries could result in black knot becoming a significant problem in Michigan.

Education needs:
- Scouting programs for black knot.
- Promote the immediate eradication of black knot infections in cherry.
- Emphasize exclusion efforts.

5. European brown rot (*Monilinia laxa*)

This pathogen is endemic in the Great Lakes region. The disease is rare; however, severe outbreaks can occur if a susceptible variety such as Meteor is planted in the region.

Carbamate and B2 carcinogenic fungicides currently registered:
- **iprodione (Rovral)**
  - Fair effectiveness

Other fungicides currently registered:
- **fenbuconazole (Indar)**
  - Highly effective.
- On Meteor **chlorothalonil** (Bravo), **fenarimol** (Rubigan), **myclobutanil** (Nova), and **sulfur** were not efficacious for European brown rot control when applied on the same schedule as **benomyl** (Benlate) + **Captan**, **iprodione** (Rovral), and **fenbuconazole** (Indar).
- **Cyprodinil (Vangard)**

Other pest management aids:
- Avoiding highly susceptible varieties.

PIPELINE
- None

"To do" list for European brown rot:
Research needs:
- Assess the efficacy of newer strobilurin and boscalid fungicides for this disease.
- Identify the susceptibility of promising new tart cherry varieties to European brown rot.

Regulatory needs:
- None

Education needs:
- Explain difference in timing of bloom sprays for European verses American brown rot.

6. Alternaria and other fruit rots (*Alternaria* spp.)

*Loss of broad spectrum fungicides could lead to increased problems with fruit rots.

B2 carcinogenic fungicides currently registered:
- iprodione (Rovral),
  - no longer effective due to recent label changes prohibiting use later than bloom.

Other fungicides currently registered:
- **Cyprodinil (Vangard)**
- **SI's**, **Captan**, **benomyl**, and **thiophanate methyl.**
  - Not effective
  - May increase the problem.

Other pest management aids:
- None

PIPELINE:
- None

"To do" list for Alternaria:
Research needs:
- Develop control strategies for Alternaria fruit rot including new fungicides.

Regulatory needs:
- None

Education needs:
- None

7. Phytophthora root and Collar crown rot (*Phytophthora megasperma, P. cryptogea, P. cambivora, P. syringae, P. cactorum*, and unidentified *Phytophthora* sp.)

B2 carcinogenic fungicides currently registered:
- None

Other fungicides currently registered:
- **mefenoxam** (Ridomil Gold)
- **fosetyl-Al** (Aliette) - non-bearing trees only.

Other pest management aids:

- Pathogens are probably present in most soils and may be present on most nursery trees therefore site selection is very important.
- Site selection to avoid soils with poor soil drainage will help avoid disease.
- Tiling of marginal soil or planting on berms.
- Use mazzard rootstock rather than the usual mahaleb rootstock on marginal soils.

PIPELINE:

- None

"To do" list for Phytophthora root rot:
Research needs:

- Screen *Prunus* germplasm for Phytophthora-resistance rootstocks as is done for apple rootstocks.

Regulatory needs:

- None

Education needs:

- Emphasize good site selection.

8. Armillaria root rot (*Armillaria mellea*, *A. ostoyae*, *A. bulbosa* and North American biological species III)

Serious disease that is taking out some of the best orchard sites. An extremely long-lived soil-borne pathogen with no known chemical control. Finding management tools to control this disease is critical to the future of the cherry industry.

Carbamate and B2 carcinogenic fungicides currently registered:

- None

Other fungicides currently registered:

- None

Other pest management aids:

- Leave land out of stone fruit production for at least 15-20 years.

PIPELINE:

- None

"To do" list for Armillaria root rot:
Research needs:

- Fundamental ways to manage this disease i.e. critical to long term sustainability
- Screen *Prunus* germplasm for sources of resistance, since current commercial germplasm with resistance is not available.
- Investigate use of biological control organisms for suppressing disease.

Regulatory needs:

- None

Education needs:
- None

9. Bacterial canker (*Pseudomonas syringae* pv. *syringae*; *P. s.* pv. *morsprunorum*)

*Blighting of blossoms and spurs, leaf and fruit spotting, bud failure (dead-bud), and cankering.

Carbamate and B2 carcinogenic fungicides currently registered:
- None

Other fungicides currently registered:
- Various copper formulations but they are not very effective due to widespread copper-resistant strains of *P. s.* pv. *syringae*. Coppers damage the foliage after a few applications (use lime as a safener).

Other pest management aids:
- Plant windbreaks around orchards.
- Maintain orchard health and tree vigor.

PIPELINE:
- None

"To do" list for bacterial canker:
Research needs:
- Establish the susceptibility of new varieties, do not introduce susceptible varieties.
- Evaluate new bactericides and plant inducers.
- Basic studies to identify genes in cherry that control the host-pathogen interactions.
- Improve our understanding of cultural practices that influence outbreaks of bacterial canker

Regulatory needs:
- None

Education needs:
- None.

10. X-disease

*Caused by a leafhopper-borne phytoplasma. Infected trees on mazzard rootstock are source for diseases spread.

B2 carcinogenic fungicides currently registered:
- None

Other fungicides currently registered:
- None. (Registration of injectable oxytetracycline was dropped)

Other pest management aids:

- Eradication of alternate hosts.
- PCR diagnostic methods are available, but not implemented.

PIPELINE:

- None.

"To do" list for X-disease:
Research needs:

- Support current efforts to sequence the X-disease phytoplasma genome. New knowledge should be gained that could lead to possible control approaches.

Regulatory needs:

- None

Education needs:

- None

11. Virus diseases

Yields losses high when virus-free trees are initially infected from pollen-borne inoculum; then gradual decline in yields for the remaining life of the orchards. Trees propagated on virus-sensitive rootstocks can be killed when infected.

Carbamate and B2 carcinogenic fungicides currently registered:

- None

Other fungicides currently registered:

- Gibberellic acid (Pro-Gibb or Pro-Gibb plus 2X)
  - Widely used in tart cherry production to maintain competitive yields.

Other pest management aids:

- Dandelion control, ground cover management, nematode control for tomato ring-spot virus.
- Planting of virus-free nursery stock. Application of gibberellic acid to counteract the adverse effects of the "tart cherry yellows disease."

PIPELINE:

- None

"To do" list for virus diseases:
Research needs:

- Determine if plant inducers can be used to prevent infection.
- Screen promising rootstock selections for virus sensitivity.
- Adapt new methods for virus resistance based on coat protein and related resistance strategies.

Regulatory needs:
- Increase enforcement for virus-free stock from the nursery

Education needs:
- None

12. Crown gall (*Agrobacterium tumefaciens*)

*Serious in nurseries. Affected plants are unmarketable.

B2 carcinogenic fungicides currently registered:
- None

Other fungicides currently registered:
- Galltrol-A (*A. radiobacter* strain K84 and derivatives of strain K84): a biological control agent that provides excellent control when used as a pre-plant root inoculation.

Other pest management aids:
- Planting of symptom-free nursery stock.

Pipeline pest management tools:
- None

"To do" list for crown gall:
Research needs:
- None

Regulatory needs:
- None

Education needs:
- None

Weeds

- Weeds compete for soil moisture and nutrients in newly planted and mature orchard crops
- Weeds may host pests including plant viruses.
- Weeds can compete for pollinating bees in spring
- Mowing row middles and applications of herbicides within the rows is used to control excessive weedy vegetation in most orchards.
- Repeated use of the same or similar weed control practice results in a weed shift to species that tolerate these practices.
- A combination of weed control practices or treatments, rotation practices and herbicides is utilized to prevent weed shifts. Sod row middles are managed by mowing.
- Sods reduce soil erosion, improve traffic conditions in wet weather, and increase water infiltration and drainage.

- Growers apply lower preemergent herbicide rates on sandy or gravelly soils, or soils containing lower clay, organic mater contents, or cation exchange capacities.

The following herbicides are used for weed control on new plantings and/or established orchards: for specific information on efficacy for key weeds, see Table 5.

Preemergence broad leaves and grasses

- **simazine** (Princep)
  - Most widely used preemergence herbicide
  - Not used on first year plantings

- **oryzalin** (Surflan)
  - Requires significant moisture for incorporation

- **napropamide** (Devrinol)
  - Requires significant moisture for incorporation

- **norflurazon (Solicam)**

- **Perdimethalin (Prowl, Pendimax)**

- **Chateau (flumioxazin)**

- **isoxaben** (Gallery)

- **oxyfluorofen** (Goal)
  - Apply during dormant only

- **dichlobenil** (Casoron)
  - Granular form only (requires special equipment; therefore rarely used)
  - Late fall only

- **pronamide** (Kerb)
  - Late fall only

Postemergence annuals and perennials

- **glyphosate** (Roundup)
  - Widely used, except in first year plantings

- **paraquat** (Gramoxone)
  - Widely used
  - Annuals only

- **2,4-D Amine** (Weedar 64, HiDep)

- Broadleaf plants
- Not used first year
- Used to remove broadleaved weeds (particularly dandelion)

- **sulfosate** (Touchdown)

Postemergence grasses

- **fluazifop-P (Fusilade)**

- **sethoxydim (Poast)**

Pest Management Aids (Not stand alone)
- No effective biological control.
- 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.
- While mulch tends to have a positive impact on growth and yield, soil moisture and soil quality, mites have been a problem.

"To do" list for weed management:
Research needs:
- Continued evaluation of alternative management systems.
- More information is needed on the interaction of orchard floor management with beneficial organisms, tree nutrition, soil organisms, etc.
- Evaluate impact of 'weeds' on biological control of mites in tart cherry orchards.
- Role of 'weeds' in orchard ecology.
- Establish more reliable weed damage thresholds.
- Test new herbicides 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.

Nematodes

- Nematode damage can be minor to moderate in cherry orchards.
- Damage is likely to be seen during the first few years following planting.
- Root-lesion nematodes penetrate into the roots, tunneling and feeding in the root tissues causing permanent damage to the tree.
- Nematodes can be controlled before and after planting an orchard through chemical controls.

1. Dagger Nematode

- Can be a pathogen of cherries and it can also be a vector of tomato ringspot virus that causes stem pitting, resulting in tree mortality.
- Common throughout Michigan cherry orchards.

Organophosphate nematicides currently used:

• Fenamiphos (Nemacur 3)
- provides fair control.
- the only registered OP nematicide available in Michigan.
- the only non-fumigant nematicide registered for bearing trees.

Carbamate nematicides currently used:

• Oxamyl (Vydate)
- provides fair control.
- the only non-fumigant nematicide that can be applied as a foliar spray.
- the limitation is it is only registered for non-bearing orchards.

B2 carcinogenic nematicides currently used:

• Dichloropropene (Telone II, Telone C-17) (fumigant)
- provides very good control.
    - soil fumigation equipment required.
    - pre-plant only.

• Metam sodium (various) (fumigant)
- provides good control.
    - must be diluted three to one or more with water.
    - soil fumigation equipment required.
    - pre-plant only.

Non-chemical alternatives currently used:

- Raising a cover crop between orchards (two years out of cherry trees) before new orchard establishment.
- Work on soil organic matter and over all soil quality

PIPELINE:

• Misc. soil amendments and biological agents

"To do" list for nematodes:
Research needs:
- Need to know more about host preference in relation to cover crops
- Evaluation of biological control agents and soil amendments for control of dagger nematode
- Additional work on impact of orchard floor ground cover/management on nematode community structure.

Regulatory needs:
- Be sure nursery stock is free of tomato ringspot virus.

Education needs:
- Continue periodic updates at annual IPM school.

2. Root Lesion Nematode
- A pathogen of cherry trees that causes infectious disease.
- It's commonly distributed throughout Michigan orchards.

- It can be present in high population density in some orchards.

Organophosphate nematicides currently used:

- Fenamiphos (Nemacur 3)
  - provides very good control.
  - the only registered OP nematicide available.
  - the only non-fumigant nematicide registered for bearing trees.

Carbamate nematicides currently used:

- Oxamyl (Vydate)
  - provides good control.
  - the only non-fumigant nematicide that can be applied as a foliar spray.
  - the limitation is it is only registered for non-bearing orchards.

B2 carcinogenic nematicides currently used:

- Dichloropropene (Telone II, telone C-17) (fumigant)
  - provides very good control.
    - soil fumigation equipment required.
    - pre-plant only.
- Metam sodium (various) (fumigant)
  - provides very good control.
    - must be diluted three to one or more with water.
    - soil fumigation equipment required.
    - pre-plant only.

Non-chemical alternatives currently used:

- Raising a cover crop between orchards (two years out of cherry trees) before new orchard establishment.
- Work on soil organic matter and over all soil quality

PIPELINE:

- Misc. soil amendments and biological agents

"To do" list for nematodes:
Research needs:

- evaluation of biological control agents and soil amendments for control
- additional work on impact of orchard floor ground cover/management on nematode community structure.

Regulatory needs:

- assurance of root lesion nematode free nursery stock.

Education needs:

- continue periodic updates at annual IPM school

3. Other nematodes (Northern root knot nematode, Ring nematode, Lance nematode, Stunt nematode)

*Minor pests that can cause unthriftiness of cherry trees in isolated situations.

Organophosphate nematicides currently used:
- Fenamiphos (Nemacur 3)
  - provides good control for root knot, lance and stunt nematodes, fair control for ring nematode.

Carbamate nematicides currently used:
- Oxamyl (Vydate)
  - provides very good for root knot nematode, fair control for ring nematode, lance and stunt nematodes.

B2 carcinogenic nematicides currently used:
- Dichloropropene (Telone II, telone C-17) (fumigant)
  - provides very good for root knot, lance and stunt nematodes
- Metam sodium (various) (fumigant)
  - provides very good for root knot, lance and stunt nematodes

Non-chemical alternatives currently used:
- Raising a cover crop between orchards (two years out of cherry trees
- Before new orchard establishment.
- Work on soil organic matter and over all soil quality

PIPELINE:
- None

"To do" list for nematodes:
Research needs:
- None known

Regulatory needs:
- Root knot - nursery stock needs to be free of northern root knot nematode

Education needs:
- None known

Efficacy Tables

Table 2. Efficacy Ratings of Pest Management Tools for the Major Pests of Tart Cherries in Michigan.

Management Tools	**Insects of Tart Cherries[1]**											
	PC	**CFF**	**APB**	**PTB**	**LPTB**	**MM**	**EBM**	**Mite**	**Scale**	**GFW**	**LR**	**RC**
Organophosphates												
azinphos-methyl (Guthion)	E[2]	E		P		E	E				F-E	G
chlopyrifos (Lorsban) [3]	G		E	E	E					E	E	
diazinon (Diazinon) [3]	G	G		P-F		G	G		G		F	
malathion	P	E		P							P	
phosmet (Imidan)	E	E		P		E	E				F-E	G
Lannate	F										G	F
Organochlorine												
endosulfan (Thiodan)	-		F-G	G	G				F	F	P	
Carbamates												
carbaryl (Sevin)	F-G	G-E	F			G	G				F	E
oxamyl (Vydate)	-									P		

Alternative products registered in MI	PC	CFF	APB	PTB	LPTB	MM	EBM	Mites	Scale	GFW	LR	RC
Bacillus thuringiensis	---	---	---	---	---			---	---	G	G	---
clofentezine (Apollo)								E				
esfenvalerate (Asana)	G	F-G				E	E			E	E	G
Lamda cyhalothrin (Warrior)	G	G							E	E		G
fenbutatin-oxide (Vendex)								G				
koalin (Surround)	F	G	---	---	---			F-G		F	F	F
metam sodium (Vapam)												
permethrin (Ambush, Pounce)	G	F	P	F	P	E	E	P	F	E	E	G
propargite (Omite, Comite)												
pyridaben (Pyramite)								G-E				
spinosad (Spintor)		G					G			E	E	
Superior oil (Sunspray)			---	---	---			E	E			
azadirachtin (Neemix, Ecozin)	P											F
bifenizate (Acramite)								G-E				
Thiamethoxam (Actara)	F-G	G										G
Methoxyfenozide (Intrepid)							G			E	E	
Pyriproxifen (Esteem)							G		G-E	G	G	
Hexythiazox (Savey)								E				
Imidacloprid (Provado)	F	G										G

New Chemistries (PIPELINE)	**PC**	**CFF**	**APB**	**PTB**	**LPTB**	**MM**	**EBM**	**Mites**	**Scale**	**GFW**	**LR**	**RC**
avermectin (Agrimek)								G-E				
emamectin benzoate (Proclaim)							G			G	G	
etoxazole (Secure)								G				
imidacloprid (Provado)	F	F				---	---	---	F	NC	NC	F-G
indoxacarb (Avaunt)	G		---	---	---	---	---	---	---		F	G
mibamectin (GWN-1725)(Mesa)								G				
New Chemistries (PIPELINE)												
Pheromone mating disruption											F	P
thiacloprid (Calypso)	G	G										
Cultural Controls												
Sticky traps												
Remove old trunks and roots												
Green manure crop for 1-2 yrs												

[1] Insect abbreviations: PC = plum curculio, CFF = cherry fruit fly, APB = American plum borer, PTB = peach tree borer, LPTB = lesser peach tree borer, MM = mineola moth, EBM = eye-spotted bud moth, GFW = green fruit worm, LR = leaf rollers, RC = rose chafer.

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

[3] Compounds recently having lost registration

Table 3. Efficacy Ratings of Pest Management Tools for the Major Pests of Tart Cherries in Michigan.

Management Tools	Nematodes in Tart Cherries					
	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 4. Efficacy Ratings of Pest Management Tools for the Major Pests of Tart Cherries in Michigan.

Management Tools	Diseases of Tart Cherries in Michigan					
	Brown rot (blossom blight)	Brown rot (fruit rot)	Cherry leaf spot	Powdery Mildew	Black Knot	Bacterial canker
Organophosphates and Carbamates register Ed in MI						
captan (Captan)	F	F	F	N	N	-
chlorothalonil (Bravo)	F-G	-	E	N	E	-
iprodione (Rovral)	E	N	N	-	-	-
Sterol inhibiting fungicides						
fenarimol (Rubigan)	N	N	F	G	-	-
fenbucanazole (Indar)	E	E	F	G	-	-
myclobutanil (Nova)	E	-	F	E	-	-
propiconazole (Orbit)	E	E	F	F	-	-
tebuconazole (Elite)	E	E	F	G	N	-
Alternative products registered in MI						
dodine (Syllit)	-	P	G	N	-	-
ferbam (Carbamate) + sulfur	-	F	F	F	-	-

Fixed coppers	-	-	E	F	P	F
Sulfur	F	P	P	F	F	-
thiophanate-methyl (Topsin-M)	-[a]	-[a]	-[a]	F	F	-
Alternative products registered in MI (cont.)	**Brown rot (blossom blight)**	**Brown rot (fruit rot)**	**Cherry leaf spot**	**Powdery mildew**	**Black knot**	**Bacterial canker**
cyprodinil (Vangard)	G	N	N	N	N	N
Ziram	F	F	P	-	-	
NewerChemistries						
trifloxystrobin (Gem)	E	G	E	G	-	N
pyraclostrobin + boscalid (Pristine)	N	G	E	E	-	N

[1]Control ratings: e = excellent, g = good, f = fair, p = poor, and n = not labeled or no activity against this pest.
-[a] = widespread resistance to benomyl and thiophanate-methyl in Michigan, neither fungicide is recommended for this use.

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

	ANNUAL BROADLEAF	ANNUAL GRASSES	PERENNIAL WEEDS

HERBICIDE	Chickweed	Lambsquarters	Mustard	Pigweed	Ragweed	Smartweed	Horseweed	Yellow Pocket	Barnyard Grass	Brome Grass	Crabgrass	Fall Panicum	Sanbur	Witchgrass	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	Canada Thistle	Velvetleaf	Vetches	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.

Section III. Tart Cherry in Michigan: Background and Key Pests

Background

Michigan dominates the red tart cherry marketplace, producing about 75 percent of the crop. There are *ca.27,500* acres of red tart cherries in the state with a total of about 37,000 acres nationwide (NASS, 2005). In addition, sweet cherries account for 8,200 acres in Michigan; there are about 78,000 acres nationwide. In Michigan, the total farm value for both tart and sweet cherries is $ 50 to $70 million, depending on the size of the crops. The value added by processing, manufacturing into other products, and marketing fresh product increases the farm value about three times to *ca.* $140 to $200 million or more (MASS, 2005). Other states with commercial crops of tart cherries include Utah, New York, Washington, Wisconsin and Pennsylvania. Oregon produces some tart cherries and substantial crops of sweet cherries.

Select regions in western lower Michigan have particularly favorable soil and climatic conditions for growing cherries. Orchard soils are predominantly well drained, sandy loam to loamy sand, glacially deposited soils of low to moderate fertility, although this varies somewhat within the state. Cherries, like other fruit crops in Michigan, are grown on sloped sites to avoid spring frosts. The climate in western lower Michigan is unique because of the location on the east side of Lake Michigan. The lake has a moderating effect on temperatures, which results in long, frost-free autumns and a delayed spring bloom period.

The major variety of tart cherry grown in Michigan is Montmorency, although minor acreage of Meteor and more recently, Balaton are grown. Trees are commonly grafted to Mahaleb rootstock, with some use of Mazzard and the MxM rootstocks. Unfortunately for cherry growers, a host of pest problems, which include insects, disease-causing pathogens, and weeds, threatens cherries. Also, tree growth and vigor, and fruit ripening must be managed to maintain the health and longevity of cherry orchards.

Over time a tart cherry production system that relies on routine pesticide applications to control pests had evolved. However, industry concerns about environmental quality, worker and food safety, pest resistance to pesticides, increasing production costs, potential loss of important pesticide tools, and the encroachment of urban area on prime cherry production sites, have caused the cherry industry to carefully re-evaluate what had become the standard production system. Cherry 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.

Nearly all red tart cherries are harvested with mechanical shakers. The cherries go from the trees directly into large tanks containing 48ºF water. These tanks hold 1,000 pounds of cherries. The fruit remains in the tanks for six to eight hours, while being constantly flushed with cold water. Flushing the cherries with cold water helps cool the cherries quickly to help maintain fruit quality, washes the cherries, and helps minimize fruit bruising while en route to the processing plant. Once cooled, the cherries are taken as quickly as possible to nearby processing facilities where the fruit is pitted and either canned or frozen. On average, Michigan produces 200 to 250 million pounds of tart cherries; total U.S. production averages 250 to 300 million pounds.

Key Cherry Pests

It is critical that several key pests be effectively controlled to maintain adequate yields of quality fruit that is acceptable to consumers; in short, to maintain a viable cherry industry. Key pests include the arthropods cherry fruit fly (*Rhagoletis cinulata and R. fausta*), plum curculio (*Conotrachelus nenuphar*), and mites (*Tetranychus urticae, Panonychus ulmi*); nematodes (several species); the diseases cherry leaf spot (*Blumeriella jaapi*), brown rot *(Monolinia fruiticola*), and powdery mildew (*Podosphaera clantistina*); and weeds, among others. The damage caused by these major pests can be severe, leading to significant loss of fruit quality and marketable yield. Tree death can even result when cherry leaf spot causes early defoliation prior to a cold winter. In that case, trees fail to accumulate adequate carbohydrate to develop the necessary winter hardiness to survive a cold winter. Trees not prematurely defoliated are normally able to survive midwinter temperatures in Michigan.

All sweet and red tart cherry varieties are susceptible to these key pests. In addition, other pests periodically cause problems for cherry growers (Table 1). Appendix 1 lists the events that have shaped pest control on cherries since the 1940s. While pesticides remain an important pest management tool, it is important to note that the cherry industry has taken a proactive approach to address the many issues that surround pesticide use. They have fostered research and education to deal with the many production and social issues. Growers have adopted various practices to reduce the overall use of pesticides and to preserve the environment.

For example, reductions of 20 percent in fungicide usage for leaf spot have been achieved by spraying alternate sides of the tree at shorter spray intervals. The most important feature of the alternate-side program is the increased protection obtained when fungicide deposits are renewed frequently. Fungicide reductions also have been achieved by avoiding some early season sprays for brown rot when disease pressure is low.

The development and adoption of monitoring for cherry fruit flies has increased growers' ability to control these insects with less insecticide compared to just a decade ago. Previously, sprays for fruit flies were initiated within a few days after the first flies were detected in test sites with artificially high overwintering populations. Early sprays were necessary because there is a zero tolerance in the marketplace for cherry fruit fly larvae in the processed product. Today, with judicious monitoring, spraying may be delayed until flies are detected in individual orchards. Not only is spraying delayed, but sprays may be limited only to outside rows rather than whole orchards.

Orchard floor management. Herbicides have been widely used in cherry production since the 1960s. They have allowed growers to stop the practice of clean tillage, which reduces soil erosion that occurs in clean-tilled orchards. 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.

Key Growth Regulators. Plant growth regulators are organic compounds other than nutrients, which influence growth, development, and maturation of vegetative and reproductive plant structures. Many used commercially in agriculture are natural products, or their analogues, with low or no human toxicity, which may be isolated from plants. Only one or two plant growth regulators are routinely used in cherry production. Those used are important to maintain production, increase harvesting efficiency, and preserve the quality and safety of the product.

Because cherries are harvested mechanically, ethephon is used to promote fruit loosening, so the cherries can be removed with less physical injury to the trees. This also helps to retain the quality of the fruit during the harvesting operation by minimizing bruising. A single application of a low level (3 to 10 ounces/acre) of ethephon is applied 7 to 14 days before harvest. The compound breaks down rapidly into its component parts, ethylene gas and phosphoric acid, both natural products.

The vigor of tart cherry trees and fruit quality declines over time as trees are debilitated by a virus disease, known as sour cherry yellows. Gibberellic acid, a natural hormone found in cherry fruits, is used to counter the effect of this disease by increasing the number of short shoots called spurs. Spurs are essential to maintain long-term productivity of the trees. A single spray of gibberellic acid at less than 0.5 ounce/acre, applied two to four weeks after full bloom, restores the natural balance between flower and vegetable buds. This maintains yields and fruit quality.

Environmental Stewardship

As a group, cherry growers have been forward thinking in their approach to environmentally sound cultural and pesticide-use practices. Michigan cherry growers are engaged in a wide range of activities to reduce pesticide use and risk and to sustain or improve the quality of life for themselves, their community, and future generations. Cherry growers, individually through the production and pest management practices that they use; and collectively, through the Michigan Cherry Committee (MCC) and in conjunction with Michigan State University, initiate and support activities designed to improve cherry production using the best technical practices. This reduces risk to growers and the environment, and insures that consumers receive wholesome fruit.

The MCC is authorized by a Michigan law allowing growers to tax themselves to generate funds to achieve the above goals. The MCC consists of nine industry members appointed by the governor from a pool of industry leaders nominated by the growers. The MCC funds research, extension, and marketing projects considered most critical for the future of the red tart cherry industry. Approximately 65 percent of the $130,000 available annually for cherry research is allocated for projects relating to cherry IPM and other pesticide reduction techniques.

A Work in Progress

Pest management strategies and tactics developed over the past 10 to 15 years have led to substantial reductions in pesticide use on cherries. The greatest reduction has come from implementing monitoring programs for cherry fruit flies and plum curculio. In addition, the use of alternate row application of insecticides and fungicides has helped. Spraying only outside rows once populations of pests from outside the orchards are detected migrating into the orchard also reduces pesticide use. Orchard scouting and other monitoring techniques, combined with alternate and border row spraying has resulted in a 65 percent reduction in insecticide use. Adoption of alternative-row-middle spraying for leaf spot has resulted in a 20 percent reduction in fungicide use. Strategies currently being researched or under development, such as reduced spray programs for plum curculio and development of better spraying technology, should result in significant additional reductions in pesticide use. However, without a major breakthrough in basic research, such as the development of horticulturally acceptable varieties that are immune to the leaf spot and brown rot disease pathogens, it is unlikely that pesticide use on cherries can be reduced much further.

As strategies to control the insects, mites, and disease-causing pathogens in cherry orchards evolve, the complex of pests will also evolve. It is important to consider cherry orchards as integrated production systems, realizing that any change made in production practices may affect the entire system. For instance, the introduction of mechanical harvesting brought with it new problems, such as borers that infested trunks of mechanically injured trees. Newer designs and use of less injurious harvesting equipment solved the problem. As another example, changes in orchard floor management are likely to affect pest management practices. Simply changing the type of compound used can have an impact on total pesticide use as well as efficacy. For disease control, the industry shifted to DMI fungicides when captafol was not re-registered, but DMI fungicides are likely to lose efficacy as the pathogens develop resistance. It is a characteristic of insects, mites, and pathogens to adapt when subjected to adversity. These changes could jeopardize the reductions in pesticide use already made in cherry orchards.

Growers have adopted various practices to reduce the overall use of pesticides. While all practices have not been universally adopted, implementation by many growers has contributed to industry-wide pesticide reduction. Educational efforts continue to encourage implementation of practical, economically viable strategies and alternatives to pesticides (when available) to further reduce pesticide reliance by Michigan tart cherry growers. Some specific examples include:

1. **Using orchard scouts and trapping devices** to insure that pesticide applications for cherry fruit flies are timely and precise.

   a. Growers and private consultants are trained to conduct weekly orchard inspections for cherry pests and beneficials. Simplified sampling procedures are used to monitor key insects and, based on predetermined threshold levels, detect the need for chemical treatment.

   b. Bait-lure traps are used to attract adult cherry fruit flies through a combination of their attractive color (canary/yellow) and the odor of ammonia given off by the bait. The flies are trapped in a sticky substance coating the trap. By inspecting traps at regular intervals, fruit fly presence and abundance can be judged. Traps, placed at the edge of cherry orchards, alert growers when sprays are needed. Pesticide use is reduced to a minimum by spraying only when needed. Further pesticide reduction for this pest is achieved by applying sprays only to alternate middle rows in the orchards or by treating outside rows rather than whole orchards.

2. **Recent plum curculio research in tart cherries.** This research has resulted in reductions of insecticides used to control plum curculio in tart cherries. Studies established that growers who have low populations of plum curculio could postpone insecticidal sprays for their control until 300 degree-days after full bloom. Any infestation that occurs before the insecticidal application will result in the larva dropping out of the fruit before harvest. This will still allow cherry growers to produce a product

that has zero larvae in it at harvest time. This practice saves growers one to three insecticidal sprays, depending on the year.

3. **Enhancing biological control of mites.** Weed-free zones under the tree during early spring, drought, and the use of pyrethroid insecticides are conditions that may contribute to damaging populations of phytophagous (pest) mites.

a. Conserving natural populations of beneficial mites is a critical part of effective integrated mite management. Habitat for entomophagous (predacious) mites *(Amblyseius fallacis* and *Zetzallia mali* are the most prevalent in Michigan) can be improved by the presence of weeds under the trees during fall and early spring. Some growers intentionally leave some weeds under the trees to enhance biological control of mites. Late spring applications of herbicides are preferred to fall applications. Scouting determines the need for additional control measures.

b. Predacious mites have developed resistance to organophosphate insecticides. When pyrethroid insecticides are used to control insect pests, the populations of predacious mites plummet, negating efforts at biological control of mites and often requiring applications of miticide. This stresses the importance of currently maintaining organophosphates as chemical control tools. In addition they are very effective at controlling fruit fly and curculio using the strategies outlined above.

4. **Pesticide reduction on control of periodic insect pests**.

a. Although rotation in a classic sense is not used in tart cherry production, growers can suppress populations of June beetle larva and nematodes by cover cropping with rye grass or sorghum for two years prior to planting a new orchard. These larva can cause a significant reduction in tree growth of young trees by root feeding.

b. Climbing cutworms can destroy developing buds and reduce leaf area on young trees. Some growers control cutworms by placing a paper, tar paper, or ‘tanglefoot’ barrier around the tree trunk.

5. **Spray application technology.** With commonly available spray application equipment, the lower parts of trees are often over sprayed in the process of ensuring adequate coverage in tops. Cherry growers are beginning to use a sprayer developed by MSU agricultural engineers Dr. Gary VanEe and Richard Ledebuhr that applies spray of controlled droplet size in a uniform curtain of air that extends from the top to the bottom of the tree. By improving delivery of spray material to the tree and hence improving uniformity of coverage, control of cherry leaf spot and brown rot also are improved, particularly in the tops of trees. With this type of equipment, chemical application rates can be reduced by 30 percent. Not insignificant, this technology also significantly reduces the amount of water required to insure adequate coverage, enhances the ability of growers to effectively utilize alternate row and border row application strategies, and reduces the potential for off-target drift.

6. **Using predictive models and management information systems** to ensure that pesticide applications are timely and precise. Disease forecasts are rapidly becoming an integral component of cherry disease management programs. Forecasting improves

disease control through more precise timing of fungicide sprays to coincide with conditions favorable for infection. Forecasting also helps to reduce total fungicide use, decreasing potential pesticide residues on the fruit and in the environment. Grower and worker safety is improved and production costs are reduced. There are currently several automated weather stations in cherry orchards in Northwest Michigan, where more than 50 percent of Michigan cherry orchards are located. Field and weather data and leaf spot forecasts are faxed and e-mailed to participating growers. This real-time information is combined with daily weather forecasts provided by Michigan State University (MSU) Extension via fax and internet. The weather forecasts are based on a National Weather Service product tailored by an MSU agricultural meteorologist to meet the needs of the fruit industry. Cherry growers throughout Michigan also can receive updated taped telephone messages with current pest control information. District extension agents maintain this service. MSU agents and specialists also conduct weekly conference calls to facilitate the production of a weekly newsletter (Crop Advisory Team Alert) sent to more than 600 Michigan fruit growers.

7. **Educating cherry growers, workers, and scouts in pesticide use/risk reduction practices and in pesticide safety.**
a. Education is a key part in Michigan's pesticide certification program. All growers must complete a minimal level of training and may also receive credits for attending educational programs to maintain their certification to apply pesticides.

b. Grower organizations and the Michigan State University Cooperative Extension Service sponsor cherry IPM training meetings and workshops, including a tree fruit IPM school, statewide IPM updates, weekly local IPM sessions during the growing season, and many other educational programs.

8. **Establishing the Michigan IPM Alliance** to promote statewide IPM adoption through research and outreach and the seeking new sources of funding for IPM.

a. In 1994, the Cherry Marketing Institute took the initiative to organize what is now called the Michigan IPM Alliance. A consortium of a dozen Michigan agriculture commodity groups, processors, and the Michigan Department of Agriculture joined together to help revitalize the MSU IPM Program. The IPM Alliance helped fund a statewide IPM coordinator and a IPM program leader for fruit and vegetables at Michigan State University. These commodity organizations have pledged a total of $70,000 per year for three years to support these positions. The two positions have been filled, which has greatly extended the depth of IPM programming and assistance in the state and helped to catalyze the procurement of additional funds for IPM research/demonstration and education. The IPM alliance is another indication of the forward thinking, which so often typifies the leadership in the cherry industry. Today the Michigan Cherry Committee continues to use industry dollars to support this critical position. We believe that strong technical people in the field is the key to long term IPM implementation.

9. **Recognizing the need for research to maintain productivity and fruit quality within the context of efficient and integrated production.** In 1978, a group of fruit growers from five counties formed the Northwest Michigan Horticultural Research Foundation in

1978 to establish a field research station. In 1979, the Northwest Michigan Horticultural Research Station (NWMHRS) station, funded by donations from the cherry industry, became a field research facility operated by Michigan State University's Agricultural Experiment Station. About three-quarters of the research projects conducted at the 100-acre station focus on techniques for pesticide reduction. Grower education at the NWMHRS is a priority because the station was funded with grower dollars. There is a strong sense of ownership by the growers. Many events are hosted at this world class cherry station and it is a showcase for the cherry industry. In the early 1990s, the growers developed the following mission statese and Risk Reduction Strategies

The Search for New Integrated Production Methods

Several innovative methods and approaches under evaluation at MSU and elsewhere may help assure consistent and economical cherry production while reducing possible environmental risks. Some examples include:

1. **Bt and insect growth regulators.** Insect growth regulators (IGR's), which interfere with the development of insects, and Bt, a biological pesticide, control insects in the order Lepidoptera. Most of the species in this order are moths and butterflies that exist as caterpillars or worms when young. Green fruit worm, an early season Lepidoptera pest of cherries, can be severe. Most pesticides applied to control other cherry pests, do not control green fruit worm and good biological control has not been developed for this pest. This results in the use of harsher pesticides that can cause secondary problems, which end up increasing the population of European red mites and two spotted spider mites. The potential of Bt and insect growth regulators for green fruit worm control and for avoiding the secondary mite problems on tart cherries is being evaluated. The potential for using IGR's post-harvest to affect the ability of key pests to successfully overwinter is currently being investigated.

2. **Pheromone disruption.** The future value of pheromones, which disrupt normal mating behavior of insects, in cherry IPM programs is still uncertain. Pheromones could work well in controlling the borer complex (greater peach tree, lesser peach tree, and American plum borers), which dramatically shorten the life of trees. Research continues to develop a pheromone dispenser that will disrupt all three species simultaneously.

3. **Spray application technology**. Research at MSU in this area continues, with a goal of improving efficiency and efficacy while reducing application rates even further. Equally significant is the fact that spray manufacturers are also developing newer systems to improve spray application efficiency.

4. **Disease resistance and plant breeding.** Development and planting of varieties with high resistance or immunity to brown rot, leaf spot, and powdery mildew could result in significant reductions in fungicide use on cherries in the future. Potential new varieties are being evaluated for many characteristics including susceptibility to diseases in small grower plantings.

   Varieties that perform well will be released to growers for further testing and eventual planting in commercial blocks. For example, while the Hungarian variety Balaton offers only minor improvements in disease resistance (compared to Montmorency), it possesses excellent fruit quality and may offer unique marketing opportunities for the industry. However, varieties that exhibit high susceptibility even to minor diseases are not released for general production. For example, an excellent quality cherry variety from Hungary was not released to Michigan growers recently because of its high susceptibility to European brown rot. This cherry variety, if grown widely in Michigan, would have increased fungicide use even on other varieties due to concerns that disease could spread from infected plantings.

MSU (in cooperation with the cherry industry) has a large tart cherry-breeding program utilizing several potential sources of disease resistance. For instance, seedlings of a cherry cultivar with field resistance to leaf spot in Hungary are also being evaluated in Michigan as a source for leaf spot resistance. Rigorous nursery and field testing is conducted to accurately establish the disease resistance characteristics of the seedling population. Although a few cherry seedlings have appeared resistant to leaf spot in nursery plantings, upon retesting they were found to be susceptible. It will take many years to find a genetically usable source of disease resistance and then to incorporate it into acceptable varieties.

Appendices

Appendix 1. Timeline of Worker Activities in Tart Cherry Orchards

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

January/February: Tree pruning & trimming, equipment repair

March: Tree pruning & trimming, equipment repair, Push & chop brush, Dormant scouting (ERM and borers)

April: Tree pruning & trimming, equipment repair, Push & chop brush, planting, insect scouting (ERM, borers, PC, GFW), disease scouting (E. Brown Rot, Bacterial Canker), Deploy deer repellant and fencing

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

- **There are no aerial pesticide applications in MI tart cherry (TC) production**
- **~ 90 day pesticide residue period from middle May to mid-August**
- **~99% of pesticides applied by MI TC industry is from closed cab sprayers with pesticide rated ventilation filtration systems (75% in Utah)**
- **~90% (50% in Utah) of MI TC growers apply pesticides using alternate row applications**
- **An estimated average of 5.5 pesticide applications are made per farm/year**
- **Orchard mowing on average done 2X/yr during 90-day residue window; average mowing time = 2 hours/10 ac, 99% with closed cab (see above)**
- **In orchard professional monitoring services average 15 minutes/10 ac scouting for insect and disease pests, weekly, 12X season; scouts regularly communicate with growers to observe REI restrictions**
- **Tree hedging: 15% of industry hedges annually, 85% of industry hedges every 2nd or 3rd yr; 40% of industry hedges from a closed cab; industry average of 4 hrs to hedge10 ac**
- **Average time in orchard raking/pushing brush = 1 hr/10 ac**
- **Herbicide applications performed on average 1X per year during 90 day residue window; average application time = 1.5 hrs/10 ac; 80% applied with closed cab**
- **< 5% of MI tart cherry industry uses supplemental irrigation; average time spent checking irrigation lines = 1 hr/10 ac 2X during residue window (100% in Utah: applies to about 25% of orchards with hand lines; but for 75% of orchards with permanent lines and sprinklers, the checking time would be about ¼ of this time; UT = *ca.* 4% of tart cherry production in US)**
- **99.8% of tart cherry harvest is performed mechanically, average of 5 hrs/10 ac with 5 people (1 shaker driver, 2 fork lifts, 1**

tank skimmer); this worker estimate represents an average crop-load (workers necessary for this operation decreases by 1 or 2 for a light crop load and increases by 1 worker for a heavy crop load).

May: weekly insect and disease scouting begins, tree hedging, bees deployed for pollination, frost protection as needed (wind machines), mowing of drive rows

Potential Spray Applications (99% in MI done with closed cab)

1. Fungicides for CLS, PM, EBR, bacterial canker and/or BR if weather conditions favorable for disease development (no leaf spot in Utah)
2. Insecticides for Green Fruit Worm, leafrollers, PC, Rose chafer, APB, and/or BCA if populations require control
3. Herbicides if weather conditions favorable for weed development
4. Tree growth regulators when tree reaches 3-5 full sized leaves

June: weekly insect and disease scouting continues, mowing of drive rows, remove dead wood (older blocks, wind damage), tree hedging, check irrigation lines, prepare harvest machinery and trucks

Potential Spray Applications (99% in MI done with closed cab)

1. Fungicides for CLS, PM if weather conditions favorable for disease development
2. Insecticides for PC, borers, scale if populations require control
3. Herbicides (clean-up sprays)

July: weekly insect and disease scouting continues, mowing, harvest preparation (cold water tank service and distribution), harvest begins; transport tanks to orchard and return them to the cooling pad.

Potential Spray Applications (99% in MI done with closed cab)

1. Fungicides for CLS, BR if weather conditions favorable for disease development
2. Insecticides for CFF, mites, scale, Rose chafer if populations require control
3. Herbicides (clean-up sprays)
4. Tree growth regulators – on average 10 days prior to harvest
5. Post-harvest leaf spot, borer, mite, CFF, PC where warranted

August: pruning, clean up

Potential Spray Applications (99% in MI done with closed cab)

1. Fungicides for CLS as needed

2. Insecticides for CFF, PC, mites as needed; less than 1% of the industry practices postharvest CFF and PC sprays now, but with less efficacious OP-alternative insecticides, growers will likely be forced to extend their residue period post-harvest to suppress growing populations in the future
3. Herbicides (applications at this time to replant and young trees only)

Sept/Oct/Nov/Dec: fertilizer applications, limited herbicide applications, tree pruning & trimming, equipment repair

Appendix 2.Contributors to the background material for this Document

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6. Dr. Alan Jones, Professor, Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan.

7. Dr. Charles Kesner, retired Coordinator, Michigan State University Northwest Michigan Horticulture Research Station in Traverse City, Michigan; currently Director of Production Research for the Cherry Marketing Institute, Lansing, Michigan.

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Special thanks to Wilfred Burr, Office of Pest Management Policy, USDA for his contributions and for facilitating the May 26 workshop.

Appendix 3. Events which have shaped pest management programs in Michigan.

Year(s)	Event
1940s	USDA implements a zero tolerance regulation for cherry fruit fly maggot. This requires growers to maintain stringent control of this insect to meet this regulation.
1950s	Introduction of organic insecticides and fungicides to replace metal containing pesticides.
1960s	Development of herbicides allow the cherry industry to replace the highly erodible practice of clean tillage with sodded orchard row middles and herbicide strips.
1960s	Introduction of mechanical harvesting of tart cherries. Borer problems increase due to increased injury to bark caused by mechanical harvesting. Trees are pruned higher for mechanization making pest control and spray coverage more difficult.
1969	Captafol introduced; becomes a dominant fungicide on cherries for leaf spot and brown rot control.
1970s	Improved shaker technology to mitigate tree injury is introduced. This reduces the number of sprays required for borer control.
1972	Benomyl introduced for use on stone fruits. Benomyl resistant *Monilinia fructicola* and *Blumeriella jaapii* detected in late 1970s, greatly reducing the efficacy of benomyl and thiophante-methyl for brown rot and leaf spot control.
Mid-1970s	MSUE establishes Code-A-Phones to inform growers about production and pest management issues, weather reports, etc.
Late 1970s	Increased grower recognition of pesticide issues like resistance, residues and the environment.
Early 1980s	Introduction of orchard scouting and bait traps results in a significant reduction in insecticide use for cherry fruit fly control.
Early 1980s	Increased use of border sprays and alternate row spraying.
1983	Research initiated at MSU to improve sprayer technology, leading to reduced pesticide rates.
Mid-1980s	Manufacturer withdraws captafol from marketplace due to re-registration costs. Other cherry fungicides not re-registered include phygon, glyodin, and cyclohexamide. Result: Increased number of fungicide applications.
1987	Fenarimol registered initiating use of DMI fungicides for cherry leaf spot; followed by registration of myclobutanil. More spray applications are required with DMI fungicides than with captafol.

1987	First commercial unit of MSU’s new sprayer technology available through Curtec. Design continued to improve throught 1990s.
1988	Fax network established by MSUE to update growers about pest management options, production issues and weather.
1989	Alar (diminozide) scare. Focuses public's attention on pesticide residues in foods and results in cancellation of its use on cherries and other fruits.
1980s – 1990s	Increased consumer awareness of food safety and environmental issues.
Early 1990s	Study conducted at MSU on plum curculio results in a strategy for decreased insecticide use.
1994	Large number of tart cherry trees defoliated from cherry leaf spot in 1993 die following the severe winter of 1993-1994.
1995	Two new DMI fungicides (fenbuconazole and tebuconazole) registered on cherries.
1996	Strobilurin Fungicides introduced
2006	Widespread resistance to SI fungicides is identified
2006	USEPA announces phase-out of azinphosmethyl use by 2012, with yearly reductions in lbs. AI/ac between 2007-2012

Appendix 4. Toxicity of pesticides to mite and aphid predators

Material	Mite Predators				Aphids	
	Stethorus adults	Stethoru s larvae	Amblysei us fallacis	Zetzel lia mali	General Aphid- oletes	aphid predato rs
Insecticides/miticides						
Abamectin	++	++	++	++	-	-
Acetamiprid	++	++	+	+	++	++
azinphosmethyl	+	+	+	+	+++	++
Bt	0	0	0	0	-	0
Carbaryl	+++	+++	++	++	+++	++
Chlorpyrifos	+	+	++	++	-	++
Clofentezine	0	0	+	+	+	+
Diazinon	+	+	-	-	+++	++
Dicofol	+	+	++	+	+	+
Dimethoate	+	+	+++	-	+++	++
Emamectin	+	+	0	0	?	?
Endosulfan	++	++	+	-	++	++
Esfenvalerate	+++	+++	+++	++	++	+++
Fenbutatin Oxide	+	+	+	+++	+	+
Fenoxycarb	+++	+++	0	0	+	++
Formetanate HCL	+	++	+++	++	-	++
Hexythiazox	0	0	+	+	-	+
Imidacloprid	++	++	+	+	-	++
Indoxacarb	++	++	+	+	++	++
Kaolin	+++	+++	?	?	?	++
Malathion	-	-	-	-	-	-
Methomyl	++	++	+++	++	+++	+++
Methoxyfenozide	0	0	0	0	0	0
Methyl parathion	+	+	+	+	+	++
Oil	+	+	++	++	-	++
Oxamyl	++	++	+++	+++	++	++
Permethrin	+++	+++	+++	++	+	++
Phosmet	+	+	+	+	0	+
Pirimicarb	+	+	+	+	+	+
Pyridaben	++	++	-	-	-	++
Pyriproxyfen	++	++	0	0	+	++
Soap	++	++	-	-	-	++
Spinosad	0	0	0	0	0	0
Tebufenozide	0	0	0	0	0	0
Triazamate	+	+	+	+	+	+

+ = 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.

Adopted 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.

Appendix 5. Classification of Pesticides

Chemical group	**Human Risk Assessment**
Carbamate	Acetylcholinesterase inhibitor; disrupts the nervous system.
Organophosphate	Acetylcholinesterase inhibitor; disrupts the nervous system.
B2 carcinogen	Likely human carcinogen.
C carcinogen	Possible human carcinogen for which there is limited animal evidence.
D carcinogen	There is inadequate evidence to determine carcinogenicity in humans.
E chemical	Evidence of non-carcinogenicity in humans.

Appendix 6. IR-4 New Pest Control Technologies.

Compounds Under Evaluation in the IR-4 Program:

Chemical Name	Trade Name	Chemical Class	Registrant	MOA	Pest Comple
Rynaxypyr	Altacor	Phthalic Acid Diamides	DuPont	Ryanodine receptor modulators	Lepidoptera Diptera
Flubendiamide	BELT	Phthalic Acid Diamides	Bayer	Ryanodine receptor modulators	Lepidoptera Diptera
Spinetoram	Delegate	Spinosyns	DOW	Nicotinic acetylcholine receptor agonists	Lepidoptera Coleoptera, Diptera
Metaflumizone	Alverde		BASF	Sodium Channel Blocker	Lepidoptera Coleoptera, Diptera
Flonicamid	Beleaf	Pyridinecarboxamide	FMC	Potassium Channel Blocker	Aphids, Plantbugs

For more information about IR-4 please see: www.cook.rutgers.edu/~ir4

Appendix 7: Tart Cherry Pest Management Strategic Plan Workgroup Participants

Tart Cherry Pest Management Strategic Plan Workgroup Participants, May 5, 2000

Bird	George	MSU, Nematology
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Tart Cherry PMSP Workgroup Invited Participants, May 26, 2000

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