TART CHERRY AZINPHOS-METHYL TRANSITION STRATEGY

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Special acknowledgement to Jeanette Wilson

I. PROFILE

A. Crop and Regions

i. Regional background

The United States Environmental Protection Agency is executing a phase-out of azinphos-methyl (AZM), an organophosphate insecticide, in US cherry production by the year 2012. This phase-out forces the tart cherry industries of the Upper Midwest and Western US to find alternative means of controlling pests and maintaining the current zero tolerance policy of worms in harvested fruit. Of the approximate 37,000 acres of red tart cherries nationwide, roughly 27,300 of those acres are in Michigan (NASS, 2006). More than 98% of the US tart cherry value is in processed product. Michigan, Wisconsin and Utah account for just over 90% of total US production, and MI alone represents approximately 75% of the nation's tart cherry production with over 206 million pounds produced in 2006 (MASS, 2006), and over 190 million pounds produced in 2007 (NASS, 2007). The US tart cherry industry has a utilized production value of over $100 million (NASS 2006) and an ancillary value to rural US economies in excess of $300 million annually, including the annual MI Cherry Festival (Cherry Marketing Institute).

Utah has the next highest tart cherry acreage, at 7.6 %, followed by New York and Wisconsin, each with 5 %. Tart cherry production in Utah, New York, and Wisconsin is approximately 28 million, 10.4 million, and 4.5 million pounds, respectively (NASS 2007).

ii. Critical Sensitivities Associated with Production

The phase-out of AZM causes growers to find alternate means of pest protection, mainly in the form of "reduced-risk" and "organophosphate-alternative" compounds. However, a compound that is "reduced-risk" for humans is not necessarily reduced risk for the environment or the ecosystem as compared to an AZM-based program.

AZM is very efficient, with short residues, proven curative abilities (Wise *et al*., 2006) and in the best integrated pest management blocks, growers need only 2-3 alternate row sprays. AZM has essentially set the industry standard, and terminating its use without a feasible alternative plan will have dire consequences for the tart cherry industry. With some of the replacements, there is uncertainty in the ability to meet industry standards of zero infested fruit in processed product (*See section* I.C.i). In an effort to maintain this standard, growers may have to increase the number of sprays, causing the cost to growers to increase approximately 1.76x (*See section* II.E.i) and a possible extension of the growing season (*See section* I.C.iii). With these changes also come projected ecological and environmental impacts, including more detectable residues, and possible detectable residues at harvest (*See section* I.C.iv).

B. Pests currently controlled by AZM

Tart cherry growers are faced with several critical arthropod pest challenges. Losses to the industry can come from internal feeding and egg-laying damage from cherry fruit fly (*Rhagoletis cingulata* and *Rhagoletis fausta*) and plum curculio (*Conotrachelus nenuphar*), the two key pests in over 95% of the tart cherry industry (M. Whalon, personal communication), along with damage from borers. Larvae of both plum curculio and cherry fruit fly feed internally in the fruit and they can damage over 50% of the crop annually (J. Nugent, personal communication). The Food Quality and Protection Act (FQPA) cancellation and mitigation changes targeting critical OP insecticides have severely curtailed the industry's potential to maintain worm-free processed cherries for cherry fruit fly and plum curculio alike. Critical biopesticide and alternative approaches to managing these pests are necessary if the tart cherry industry is to survive the AZM cancellation.

i. Plum curculio

Plum curculio (PC) populations occur in Michigan, Wisconsin, New York, Washington, and Ontario, Canada. Plum curculio populations also occur in Utah adjacent to tart cherry production where this species is a quarantine pest and an increasing menace to western tree fruit production systems. To date, other major west coast fruit producing regions have escaped the introduction of PC, but recent introductions of the apple maggot into the Columbia River Basin and the presence of the PC's principal wild host, *Prunus americana*, in most of the river drainages in the Intermountain and Pacific Northwest make PC one of the most significant potential invasive threats to these industries as well (Whalon, 2000).

PC overwinter as adults and are active as soon as temperatures reach 15ºC in the spring (Howitt, 1993). Mating occurs before and during bloom while the adults feed primarily on leaves and flowers at this time. Fruit feeding and oviposition commence with shuck split as the new cherries rapidly swell. PC adult feeding and egg-laying continue through most of the production season (158-800 degree-days base 50 ºF) (Figure 1) while oviposition between 300 and 800 degree-days resulted in detectable larvae in the fruit at harvest (Hoffmann *et al*., 2006). During this period, PC feed almost exclusively on very rapidly expanding cherry fruit tissue (Hoffman *et al*., 2006), and lay hundreds of eggs per female (Howitt, 1993), making it difficult to maintain coverage using OP-alternatives and reduced risk compounds that depend on ingestion, and often resulting in failure to prevent oviposition in the crop. Therefore, while many of these newer reduced risk and OP-alternative compounds work on other crops like apple; they fail for tart cherry producers. Without adequate contact toxicity or dramatically suppressed orchard and surrounding landscape population reduction, many otherwise effective insecticides, which are dependent on ingestion as a mode of action, fail to protect the harvest from infested fruit (Wise *et al*., 2007). As the industry is being forced by the FQPA to change to these new chemistries, severe consequences have ensued for both growers and processors (IOMP, 2006).

A PC phenology model based on degree day (DD) base 50°F shows the windows for AZM (Guthion®) spray versus neonicotinoid sprays (Figure 2). Because PC must feed to kill adults, the window for neonicotinoid control is narrow when compared to that of AZM.

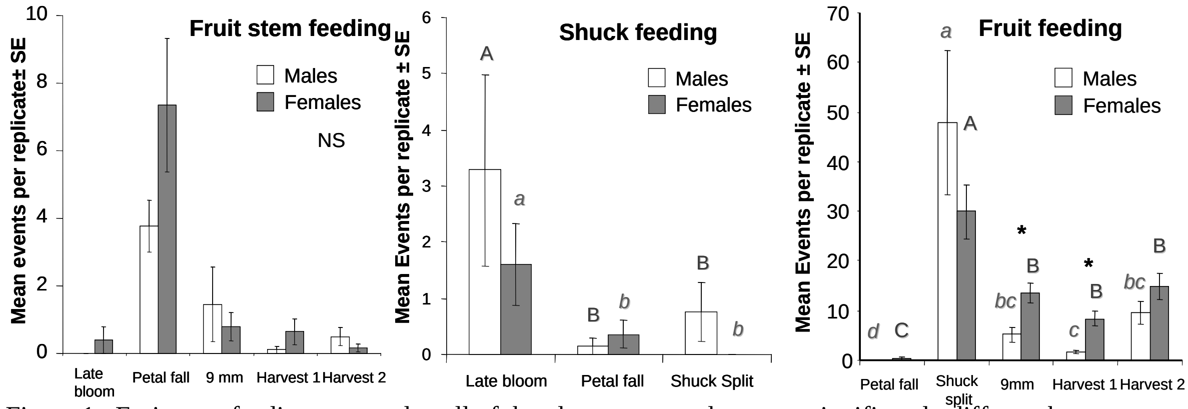


Figure 1. Fruit stem feeding occurred at all of the plant stages and was not significantly different between males and females across the periods evaluated. Shuck feeding varied by plant stage but not beetle sex within a plant stage. It was more common at late bloom than the later periods. Fruit feeding varied by fruit stage and beetle sex. There was more non-ovipositional feeding on fruits at shuck split than at other periods. *Different capital letters represent significant differences (P<0.05) across phenologies for females, different lower case letters represent differences across phenologies for males and (*) represents a significant difference between males and females for a given phenology.*

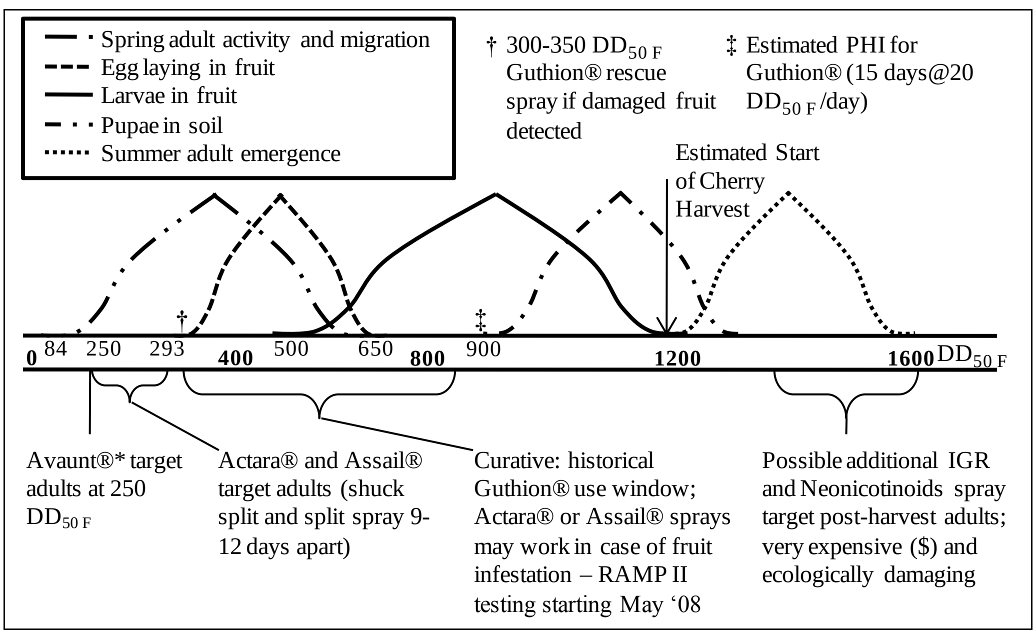


Figure 2. Preliminary plum curculio life stage control timing for reduced risk and OP-replacement insecticides (Whalon et al., 2007)

*Avaunt® may be effective but it must be ingested (no contact activity). If neonicotinoids (Actara®, Assail®, Provado®) or other compounds are applied before oxidiazine (Avaunt®), the neonicotinoid residues may reduce feeding of PC (antifeedant activity of neonicotinoids – for more details see MFMG E-154 2008) and therefore reduce Avaunt® activity.

ii. Cherry fruit fly

In some respects, Cherry fruit fly (CFF), which plagues all US cherry production regions, can be just as challenging to control as PC. Cherry fruit fly is primarily a late season pest, ovipositing in the crops close to harvest. Female CFF are sexually mature for an irregular period before first larval infestation occurs (Messina *et al*., 1991). First larval infestation is strongly correlated with fruit maturation. CFF oviposition in fruit is the critical biological observation or biofix point for subsequent sprays. Because of ovipostion close to harvest, controls are required at or near harvest time, necessitating short reentry intervals (REI) and pre-harvest intervals (PHI) for incorporation into the IPM program. Like plum curculio, cherry fruit fly pressure appears to be on the rise in Michigan cherry production regions (RAMP I 2007, unpublished), resulting in increased numbers of rejected loads. (*See section* I.C.ii).

iii. Other pests

Other pests that are currently controlled by AZM include obliquebanded leafroller (OBLR, *Choristoneura rosaceana* (Harris)), green fruitworm (GFW, *Orthosia hibisci*), and several types of borers (greater peach tree *Synanthedon exitiosa*, lesser peach tree *S. pictipes*, and American plum *Euzophera semifuneralis*). OBLR feed on the bud clusters, flowers, fruit, and leaves of the tree. They have become a significant pest, with a demonstrated propensity for developing pesticide resistance (Howitt, 1993). GFW feed on the fruit and leaves. The presence of borers significantly reduces an orchard's life. *S. pictipes* attacks the root, trunk and major scaffold cambium dramatically sapping the tree's ability to transport nutrients. Borer oviposition, feeding and gallery activity also breach the tree's primary defenses against secondary bacteria and fungal pathogens resulting in rapidly debilitating canker diseases and tree death (M. Whalon personal comment). AZM mostly kills lesser borers in the scaffolds of the trees, but Lorsban was the principle trunk spray used to control borers. However the EPA has received a request by registrants to voluntarily cancel Lorsban®, following a claim filed by farmworker and advocacy groups.

C. Projected impacts of AZM transition

i. Zero Tolerance

Federal regulations, processors, and consumers maintain a zero tolerance policy for worms in processed cherries. The cherry processing industry in the US evolved during the 'Organophosphate insecticide era' when for 35 years growers experienced outstanding control of fruit pests that would have otherwise infested fruit before harvest, depressing the marketing of a wholesome and attractive product. Now the cherry industry has become dependant upon the power of OP chemistry to meet the demanding marketplace quality standards. Historically, achieving the zero tolerance level was only possible through AZM, both as a contact and ingested insecticide. However, AZM also has curative effects. It provides back-action by killing larvae in infected fruit, (Wise *et al*., 2006) thus providing the industry with no detectable larvae in the fruit in processed product.

ii. Rejected loads

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. During the transition and subsequent to it, the tart cherry industry in the upper Midwest could expect a 3-7% increase in rejected cherries at processor receiving stations (M. Whalon, personal comment). Among growers with rejected loads, an estimated 22% of them will experience bankruptcy resulting from their infested fruit.

This latter estimation is based on an extensive review of the upper Midwest's cherry producer "crop failure forensics" and aftermath. This estimation is fortified from our experience in the RAMP I project, where in the reduced-risk blocks, two different producers in subsequent years allowed detectable plum curculio or cherry fruit fly damage in preharvest RAMP samples. This represents 11% of the 18 (with 2 growing seasons and 9 blocks) reduced risk RAMP blocks with near failure. No infested cherries were detected in processor receiving stations, but this outcome represents a probabilistic and quantifiable risk. If the rate of infested fruit detection at processor receiving stations increases by the projected 3 to 7%, a significant number of struggling small to medium sized cherry producers would likely resort to bankruptcy. Given the 13 year price received per pound average of $0.204 (SE $0.039/lb) (NASS 2004), this would mean a $0.011/lb decrease to the producer. A one cent per pound cost decrease represents approximately a 5% loss to the grower for just pesticide product. In some years and on some farms, this would be a very significant loss. Many small to medium sized growers will absorb these costs directly with no or very little prospect of passing these costs onto consumers.

iii. Post-harvest pest control

Controlling pest populations requires not only management of pest levels during the growing season, but also monitoring and control in the post-harvest season. A new monitoring protocol of placing CFF traps high in the tree canopy proved to be a more sensitive measure of CFF activity in the orchard. Monitoring revealed that the vast majority of CFF adults were present in commercial orchards after harvest, in contrast to much earlier fly catches in unmanaged cherry orchards (Figures 3 and 4). Monitoring of PC showed that adult populations were higher pre-harvest, but there was still a population present in the orchard post-harvest (Figures 5 and 6).

This pattern of increased activity after harvest has been detected in previous years because summer generations of PC and CFF feed on un-harvested cherries left in the orchard due to set-aside requirements, creating an ever-burgeoning population for the subsequent season (Figure 7). Thus, post-harvest applications are now being considered and implemented to aid in the control of post-harvest PC and CFF pressure. In the RAMP I study, growers had to apply post-harvest controls in 2004, 2006, and 2007 (Table 1).

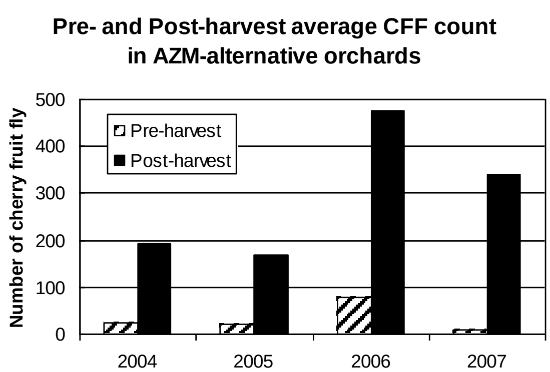


Figure 3. Average number of CFF observed in 9 reduced-risk and OP-alternative Michigan orchards.

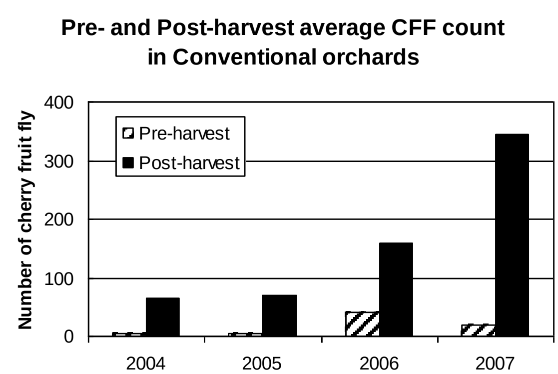


Figure 4. Average number of CFF observed in 9 conventional Michigan orchards

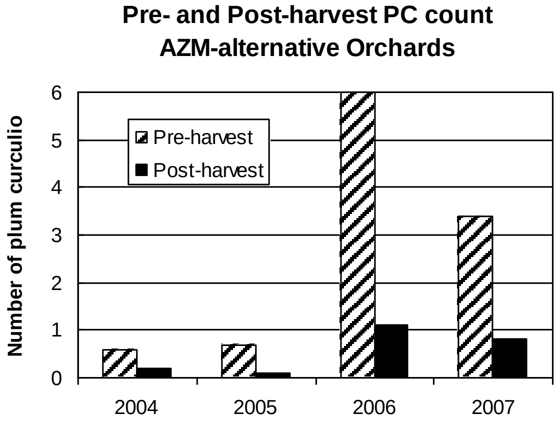


Figure 5. Average number of PC observed in 9 reduced-risk and OP-alternative Michigan orchards. Every year, the average pre-harvest count of PC was higher than the post-harvest count.

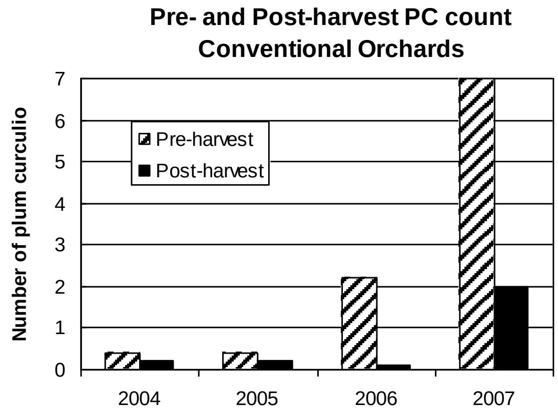


Figure 6. Average number of PC observed in 9 conventional Michigan Orchards. Every year, the average pre-harvest count of PC was higher than the post-harvest count.

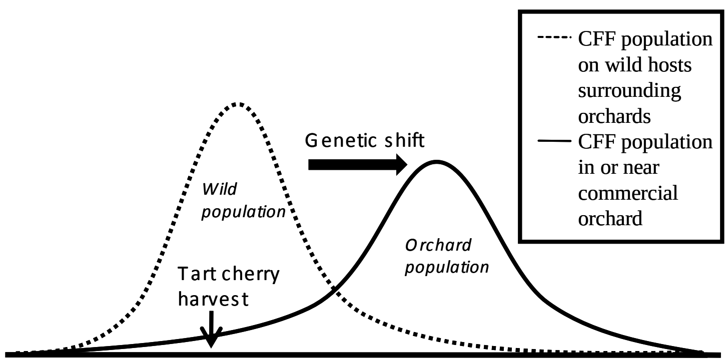


Figure 7. Postulated allochronic shift in cherry fruit fly emergence in or near commercial cherry orchards in Michigan and perhaps in other growing areas (Boller and Bush, 1973)

Table 1. Growers who used Post-harvest Sprays in 9 Michigan OP-alternative orchards

Year	Number of Growers who used post-harvest sprays
2004	3
2006	4
2007	5*

*2 growers sprayed to control PC and CFF, 3 growers sprayed miticide

iv. Residues

Another key issue that the processed cherry industry will face under the FQPA induced AZM cancellation is detectable residues at harvest from so called “reduced-risk” and “OP-replacement” compounds that growers have been forced to use. The consequences of an industry being forced to put pesticide residues on its products by the FQPA seems counterintuitive to the rational for the passage and promulgation of human health and environmental protection. Tables 2 and 3 show the results of two residue studies: one conducted pre-FQPA (Table 2) by the MDA (MDA, 1999) and the other conduction in conjunction with the RAMP I project (Table 3).

Table 2. 1998 Pesticide residue level study.
Fruit samples taken at processing plant.

PRE-AZM TRANSITION *Conventional (AZM) Orchards*		
	Residue Levels (ppm)	
Sample	*Phosmet*	*Azinphos-methyl*
1	ND	ND
2	ND	ND
3	ND	ND
4	ND	0.2

ND=no detection

Table 3. 2005 Pesticide residue level study. Fruit samples taken at processing plant

POST-AZM TRANSITION						
Conventional (AZM) Orchards			*AZM-Alternative Orchards*			
	Residue Levels (ppm)			Residue Levels (ppm)		
Sample	*Phosmet*	*Azinphos-methyl*	Sample	*Imidacloprid*	*Thiamethoxam*	*Indoxacarb*
1	ND	ND	1	ND	0.075	0.015
2	ND	0.077	2	ND	0.114	0.013
3	0.079	--	3	ND	ND	ND
			4	ND	ND	BQL

ND=no detection
BQL=below quantifiable level. The grower whose fruit was tested for sample 3 in the conventional orchards did not spray AZM.

v. IPM levels in Tart Cherry

Before the passing of the FQPA, MI cherry growers practiced advanced Level III integrated pest management (IPM). Integrated pest management is the control of pests via a combination of biological, chemical, and cultural controls. Prior to the passing of the FQPA, IPM was occurring at 2nd and 3rd levels. Post-FQPA, with the phase-out of AZM necessitating the use of alternative pest control options reverts the IPM strategy back to level one, which is little more than calendar sprays (Figure 8).

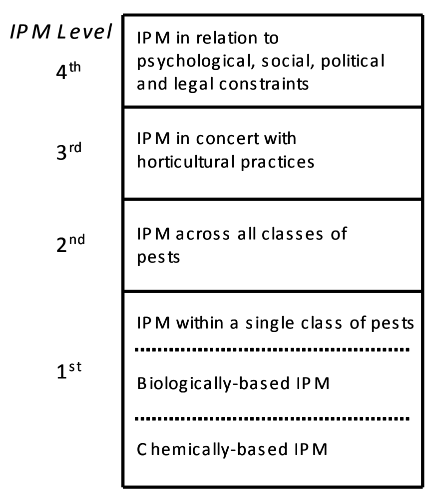


Figure 8. Advancing levels of integration in pest management (Prokopy and Croft, 1994)

vi. Ecological impact

AZM is arguably the most ecologically destructive pesticide chemistry in use in North America today. However, there are no AZM incidents associated with cherries, despite the MI cherry industry's intimate association with water systems. A 2001 report on the impact of AZM on ecosystems, fish, invertebrates, birds, etc. led USEPA officials to identify AZM as the pesticide generating over 50% of all aquatic kill incident reports in the US (EFED, 2001).

Most of the tart cherry production is located within the Great Lakes Basin, which constitutes 18% of the world's supply of surface freshwater. As a result, tart cherry producer's pesticide use practices are particularly scrutinized. A Great Lakes survey found 'sufficient presence' of pesticides of concern (USEPA 1998) in the surface waters of the state to warrant further public investments in grower changes through private/public partnerships funded by both federal and state resources (MAEAP 2004). Also, several Great Lakes National Treasures are in intimate association with the cherry industry, including the Sleeping Bear National Lakeshore, Manistee National Forest, three National Scenic Waterways, and numerous state and national fish hatcheries. Many orchards are also part of ecosystems containing threatened and endangered endemic species, including Karner Blue Butterfly (*Lycaeides melissa samuelis*), monkey flower (*Mimulus glabratus* var. *michiganensis*), Fassett's locoweed (*Oxtropis campestris* var. *chartacea*) Houghton's goldenrod (*Solidago houghtonii*), dwarf lake iris (*Iris lacustris*), Mitchell satyre (*Neonympha mitchellii mitchellii),* Indiana bat *(Myotis sodalist)* and pitcher's thistle (*Cirsium pitcheri*).

The current pesticide regulatory system is practically and scientifically designed from an acute perspective, but called upon to protect from the most common exposure, which is not acute but chronic. By looking primarily at acute toxicity, AZM appears to be a very disruptive chemistry which rapidly kills many different exposed species. Its action is relatively quick and broad spectrum, but its residues break down rapidly into various nontoxic carbon molecules. This is why AZM's ecosystem impact can be classified as "deep" (broad spectrum), but "short" (where residues break down rapidly). In contrast, an alternative chemistry may have a "shallow" but "long" impact. The comparison of how both may impact the same orchard ecologically is illustrated in Figure 9.

With AZM there are over 40 years of field use to estimate its chronic effects. Much of how AZM works in the ecosystem is known. The residues dissipate in the environment fairly rapidly (MDA, 1999), and the long-term impacts are limited in time, so chronic effects of AZM have this relatively short but deep time-related impact. This rapid breakdown is important because it keeps pesticide residue levels below detectable limits in processed products. With many of its replacements, we have very little time - less than 5 years for a few and less than 1 or 2 years for many reduced risk compounds currently favored for registration. The phase-out requires the use of these alternative pest management techniques, some of which have unknown long term ecological effects. The use of alternative chemistries and pest management options may also increase eco-impacts and outbreaks of new pests, which could take 8 to 15 years to equilibrate. (M. Whalon, personal communication).

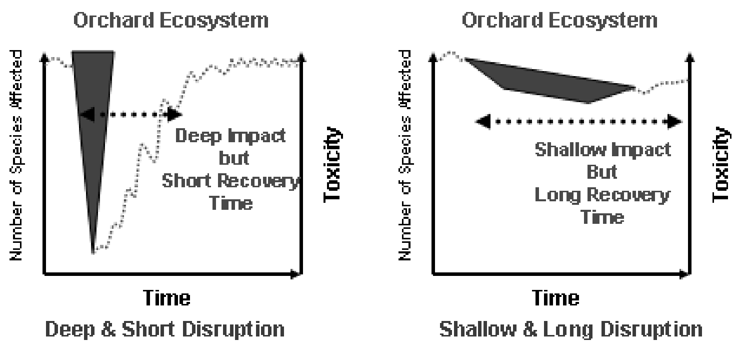


Figure 9. An illustration of different insecticides upon the ecology of an orchard. An inferred chronic residue picture from AZM versus the reduced risk neonicotinoid imidacloprid from the USDA Cherry RAMP I grant spray program in Michigan.

vii. Functional Ecology

One way to evaluate insecticide impact on an orchard ecosystem is through the study of functional ecology. Functional ecology measures diversity, evenness and richness of insects, mites and soil microbes, together with an assessment of overall tree stress levels. Essentially, functional ecology looks at patterns that indicate the condition and health of the orchard system. In the RAMP I study, Michigan State University researchers used four measures to assess the functional ecology of cherry orchards: mite predator/prey ratios, pheromone monitoring of more than thirty species of leafrollers, nematode identification from routine soil or leaf samples, and the development of an index of the degree to which trees in an orchard have been stressed (with data derived from photosynthesis measures.) By studying the patterns that result from these measures under different management systems (AZM versus Neonicotinoids), a grower can better understand the patterns associated with nutrient status of the trees, changes in pest pressure from surrounding areas, pesticide impacts on beneficial species and from this analysis infer sustainability of one set of practices versus another.

Functional ecology data, when compiled across time, orchards, and areas can be a very powerful tool for diagnosing the environmental and ecological condition of the orchards collectively. A working understanding of functional ecology provides fruit growers with the advantage of having an indicator or measure of how “healthy” or “sustainable” a production system is, and also as a means to help maintain pest management tools. Particularly with the passage of the FQPA and with heightened concerns for worker safety, pesticide residues, and ecological impacts of pesticides, growers need functional ecology data to defend safe and environmentally healthy practices, along with the pesticide tools that are critical for economic competitiveness.

In RAMP I, natural enemy surveys that were conducted in reduced risk orchards and in conventional orchards with organophosphates were used to compare the ecological “health” of each of the orchards. The presence, diversity and quality of sixteen different groups of beneficial insects (e.g. bees, predators, parasites, etc.) were monitored and compared. A species diversity index was developed for each of the conventional and reduced-risk blocks in 2007, along with calculations of the evenness and richness. High diversity is considered to be indicative of a well-functioning biological system, thus higher indices would indicate a healthier orchard. The ecological health rating was delivered in the form of a dollars-per-acre figure, based on a weighted summation of the number of natural enemies sampled in each orchard. The data from the survey found that the conventional (OP) orchards had both higher diversity and greater natural biological control (in terms of $/acre from beneficial) than the reduced-risk orchards (Table 4). The AZM orchards were therefore "healthier" ecologically than the OP-alternative orchards based on these measures of higher natural enemy or beneficial insect diversity, and the higher economic payoff from biological control. This likely resulted because AZM has been used for many years, so the orchard populations have adjusted over time, whereas the introduction of new chemistries affects not only the target pests but also beneficial natural enemies.

During the phase-out of AZM, it is critical to continue natural enemy sampling and functional ecology analysis for new chemistries or combinations of replacements. It would be detrimental to find a chemistry that achieves initial economic success in the form of lower pest numbers, only to find that natural enemies and orchard beneficials had been affected as well, altering the ecological stability and sustainability of the orchard.

Table 4. Financial benefit ($) per acre to growers from the presence of natural enemies in reduced-risk/OP-alternative and conventional (AZM) orchards in 2006 and 2007. Figures based on a calculation of $0.05 per natural enemy.

	2006		2007	
Grower	Alternative	Conventional	Alternative	Conventional
1	$ 8.05	$ 8.05	$ 4.03	$ 12.08
2	$ -	$ 12.08	$ 20.13	$ 24.15
3	$ 4.03	$ -	$ 16.10	$ 28.18
4	$ -	$ 12.08	$ 12.08	$ 36.23
5	$ 12.08	$ 24.15	$ 8.05	$ 16.10
6	$ 20.13	$ 64.41	$ 20.13	$ 52.33
7	$ -	$ 8.05	$ 4.03	$ 36.23
8	$ 36.23	$ 48.31	$ 12.08	$ 24.15
9	$ 12.08	$ 16.10	$ 44.28	$ 4.03
Sum	$ 92.59	$ 193.22	$ 140.89	$ 233.48
Average	$ 10.29	$ 21.47	$ 15.65	$ 25.94

viii. Secondary pest concerns

An AZM-alternative IPM system needs to consider not only the primary target and secondary pests, but also any instability or rebound species in the orchard system. With the termination of AZM use, it is unknown whether or not there will be an increase in rebound species populations, including Mineola Moth (*Acrobasis tricolorella*) and mites. Mineola moth is of a particular concern since it was a key pest in cherry production in the Upper Midwest prior to the introduction of organophosphate insecticides in the late 1940s and early 1950s (Howitt, 1993).

Mineola Moth. Overwintering larvae of the Mineola Moth feed on fruit buds and developing flower parts. More serious damage is caused by the second generation that emerges in June. These larvae enter and feed on the cherries, and may be present in the fruit at harvest. To provide effective control, chemicals should be sprayed on both sides of the row, since spraying alternate sides does not give adequate coverage. (Howitt, 1993). This is a concern for alternative IPM programs, since many of them try and reduce to alternate row spraying.

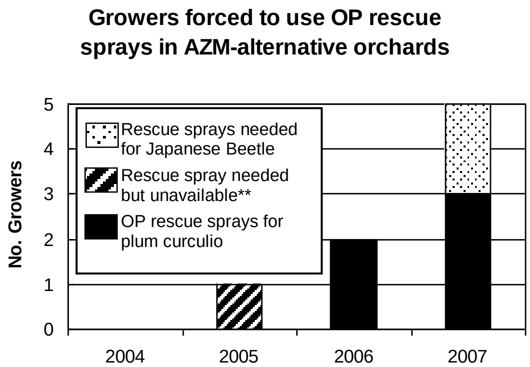
Mites. The mite species complex can be used as an ecological indicator system, and in cherries can detect disruption (pests escaping biological control) in the environment. Mite complexes can also be used to determine the relative sustainability of an orchard ecosystem that has been exposed to various combinations of management strategies. Mites fill a large number of terrestrial niches as predators, herbivores and fungivores. In the orchard ecosystem, members from each niche can be found at varying times throughout the growing season. Mites are good indicators of agricultural sustainability for many reasons, most notably because they occur in some capacity in every management strategy of Michigan orchards (Coombs *et al*., 2003). Mites are also known to be affected by many management practices and ecosystem characteristics, including pesticide use. Sensitivity to environmental changes results in a change in the pest to predator ratio. Observations of the patterns of this varying ratio are the key to using a mite species complex as an ecological indicator. (Strickler *et al*., 1987). Data from the RAMP I project showed that increasing numbers of growers needed to use miticides from 2004 to 2007 (Table 5).

Table 5. Results from nine Michigan growers who had to apply miticides to reduced-risk and OP-alternative orchards

Year	No. of Growers	
	Alternative	Conventional
2004	0	0
2005	3	1
2006	1	1
2007	5	2

ix. Summary of Projected Impacts

Data from RAMP I essentially showed that without AZM, there is no "transition" (Figures 10 and 11). Reduced-risk and OP-alternative orchards experienced failure and had to revert back to organophosphate use. With many of the AZM alternatives, growers are forced to use a greater number of sprays to achieve the same effective control of pests that was accomplished with the use of AZM. With newer chemistries, there is a greater uncertainty in the effectiveness of pest control, along with greater uncertainty in the ability to maintain the zero tolerance policy standards. If reduced risk and OP alternative compounds cannot achieve this standard, then there will be greater rejected loads, resulting in severely detrimental economic consequences for growers.



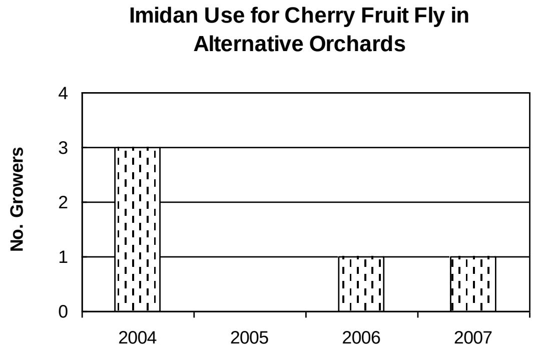


Figure 10. The number of Michigan Growers who resorted to organophosphate rescue sprays based on pest pressure in the orchard. The numbers are only indicative of those growers who sprayed Guthion® or Lorsban® in the OP alternative blocks, with excessive pressure from PC.
**In 2005, one AZM-alternative orchard had PC infested fruit that were discovered inside the PHI for AZM (14 days). Therefore, the executive team worked with the grower through a process of very intense monitoring to determine when PC larvae had completely dropped from the fruit before the block was harvested. This incurred significant fruit quality compromise for the grower and a significantly reduced price per pound.

Figure 11. The number of Michigan Growers who sprayed Imidan in AZM-alternative orchards to target excessive pressure from CFF.

II. POTENTIAL PEST MANAGEMENT STRATEGIES & TOOLS

A. Pest Management Tools (including chemicals, biologicals, and practices)

The following list is a compilation of currently available AZM alternatives. A key focus for each is its ability to control the main tart cherry pests plum curculio and cherry fruit fly. (For a summary of key insecticides for use against plum curculio, see Table 13). Any compound listed with less than excellent control of these two pests will not stand up to the zero tolerance policy for processed product. However, to provide an effective alternative to AZM, each alternative must be considered for more than its major pest control. The control of secondary pests, impact on natural enemies, ecological impact, and any shortcomings must also be considered. To provide effective control of AZM, it is likely that several chemistries will need to be used together in an IPM system, along with special practices.

i. Organophosphates

These compounds are under the IRAC mode of action (MOA) classification acetylcholine esterase inhibitors, subgroup 1B.

•*Phosmet* (Imidan®)

As the sister product to Guthion®, Imidan® is the second most widely used insecticide for PC and CFF control in tart cherries. It provides excellent control of PC, but has no curative effects and therefore does not eliminate larvae in fruit at harvest in high pressure sites. It provides excellent control of CFF, but it has a shorter residual effect than Guthion®. Imidan® has a 7-day PHI, which is one reason for its increased use, especially as an option close to harvest, because AZM's PHI has increased over the last number of years. It provides effective control of some lepidoptera, but requires more applications with greater functional ecology and other environmental effects. It is softer on predator mites, which probably relates to its shorter residual mortality, and it is easier on beneficials than other OPs if the same number of sprays were applied. However, it is harder on beneficials if more phosmet sprays are required than AZM sprays. Additionally, Imidan® cannot be used on sweet cherries, because it causes phytotoxicity, rendering the product unfit for processing.

•*Diazinon*

This has good effectiveness for PC, but with potential phytotoxicity. It is not used for CFF control.

•*Chlorpyrifos* (Lorsban®)

Lorsban® is registered for foliar use in apples only up until petal fall, so its use for in-season pests is limited. It can also be used for trunk sprays for borers, which is generally applied every other year. Many growers harvest with mechanical shakers, to reduce worker exposure and for increased economic benefit. The shakers can damage the trees though, and the pitchout contains volatiles which attract borers. Currently, chlorpyrifos is under review by the EPA, following a petition (EPA docket: EPA-HQ-OPP-2007-1005) from the National Resources Defense Council and Pesticide Action Network North America requesting the cancellation of registration for chlorpyrifos.

•*Malathion*

If ultra low volume (ULV) formulation is applied, it provides excellent control of CFF. However, ULV formulation is not used because it is usually applied by aerial application, which is not practiced in cherry orchards. Malathion provides poor effectiveness for PC. These two flaws essentially assure that Malathion is not an AZM replacement.

ii. Neonicotinoids

These are an expanding group of alternative insecticides that are primarily active against leafhoppers, aphid and leafminers; however, a few appear to have a broader range of activity. Neonicotinoids belong to the Nicotinic Acetylcholine receptor agonists/antagonists main group of the IRAC MOA classifications, in subgroup 4A.

•*Thiamethoxam* (Actara®)

Field data from RAMP I farms from 2004 to 2007 suggest that Actara® can not be used alone against PC at the label rate of 5.5 oz per season. (See Figure 2). However, EPA recently expanded Actara® use to allow for two full sprays totaling no more than 8oz/acre per season. It is known to provide good control of CFF (Liburd *et al*., 2003). Actara® has a 14-day PHI, which inhibits control of CFF close to harvest when this pest is most active. It has some curative abilities, but is toxic to wildlife and highly toxic to aquatic invertebrates and bees. It is also hard on natural enemies.

•*Imidacloprid* (Provado®)

Provado® provides good control for CFF (Wise *et al*., 2004). It has 7-10 day residual activity, and a 7-day PHI with a 12 hour REI. It must be ingested by the pest to be effective. Provado® is only labeled for suppression of PC, not control, so is rated as fair.

•*Acetamiprid* (Assail®)

Assail® can provide good to excellent control of PC, codling moth, and oriental fruit moth. However, the primary route of entry into the target pest is ingestion and United Phosphorus Inc. (Cerexagri-Nisso LLC) is not supporting MRL's in the tart cherry international market (eg. Germany and Poland).

iii. Other registered insecticides and biological controls

•*Carbaryl* (Sevin®) – IRAC MOA class 1A: Carbamates
Sevin® provides fair to good control of PC, but use of Sevin® leads to easily detected and extensive residues in processed products. Control of CFF under a carbaryl IPM program provides good to excellent control of CFF, but short residuals require more frequent sprays. Sevin® is disruptive to mites, natural enemies, and established IPM programs. It also has potential phytotoxicity on cherries. Overall, it is not a viable AZM alternative.

•*Esfenvalerate* (Asana®) – IRAC MOA class 3: Pyrethroids
Control of PC is good if Asana is used at high rates, but it is not effective at reduced rates or alternate row spraying. Control of CFF is poor to fair, not providing effective enough control to meet zero tolerance requirements, so it is not used for CFF. Asana has short residual action, and low-term disruptive activity to predator mites. Therefore, Asana is not recommended where growers intend higher order IPM programs.

•*Permethrin* (Ambush®, Pounce®) – IRAC MOA class 3: Pyrethroids
Control of PC is good if used at high rates, but it is not effective at reduced rates or alternate row spraying. Control of CFF is fair. The short residual requires more frequent applications, and these Permethrin chemistries are disruptive to predator mites and established IPM programs. There are also aquatic toxicity problems, mite flaring and other non-target effects.

•*Spinosad* (SpinTor®, Entrust®, GF-120 NF Naturalyte®, Success®) – IRAC MOA class 5: Spinosyns
Spinosad is a naturally derived spinosyn-based insecticide that has shown good activity against several tree fruit pests (Sparks *et al*., 1998) and is registered for use in tart cherries. The Spinosad chemistries have been shown to provide excellent control of leafrollers and leafminers (Beers, 1996; Reissig *et al*., 1997), and more recently, Smith (2000) reported good efficacy against Western cherry fruit fly in small-plot trials using Success® alone or with oil. It is not fast acting, and requires ingestion to be lethal. It has 7-14 day residual control, with a 7-day PHI. Entrust® is registered for use in organic production, with 7-10 day residual control. GF-120 NF® provides fair control with bait formulation, and is also registered for use in organic production. Although spinosyn is registered for control of CFF in cherries, growers have been reluctant to incorporate it into their IPM programs, as it does not provide sufficient control to meet zero tolerance (Pelz *et al*., 2005), and all of these Spinosad chemistries are prohibitively expensive.

•*Spinetoram* (Delegate™) – IRAC MOA class 5: Spinosyns
Delegate™ is a new spinosyn product with broad spectrum activity, but its efficacy for CFF control has yet to be determined. It may be used for suppression only of PC because it requires ingestion, but right now the manufacturer only rates it as good, suggesting inferior activity.

•*Indoxacarb* (Avaunt®) –IRAC MOA class 22A: Indoxacarb

Avaunt® provides good to excellent control of PC, but complete coverage of the crop is critical for control, since the primary route of entry into the target pest is ingestion. Because of this, Avaunt® must be used early to be effective, before any neonicotinoids with antifeedant properties are applied. One significant drawback with indoxacarb is that it is toxic to bees. This is particularly troublesome because early spring pesticide application timing in cherry for PC control occurs at or near petal fall. Therefore, indoxacarb has a low functional ecology rating because of its likely impact on native pollinators which tend to forage on pollen in cherry orchards long after petal fall.

•*Kaolin* (Surround®)

Surround® provides fair control of PC, with insufficient efficacy for the zero tolerance standard. It provides good control of CFF. Maintaining coverage is difficult with rainfall, so it requires many applications. Surround® is not used in most Great Lakes region orchards, and some processors will not accept it because it spots the fruit with difficult-to-remove residues.

•*Entomopathogenic fungi*

In addition to entomopathogenic nematodes (*See* II.A.iv *below*), EPA-regulated biopesticides such as entomopathogenic fungi offer the opportunity to attack previously untargeted pest life stages, including the soil occupying late instar larvae, pupae and enclosed adults of plum curculio. *Beauveria bassiana* (*Bb*) is a fungal pathogen of insects already available on the market as a soil spray application (Mycotrol®, Mycotrol0® Botanigard®ES, Botanigard®22WP, and Naturalis®L), but the economics of practical use preclude a soil spray strategy for specialty crop growers. Three strains of *B. bassiana* are registered by USEPA; two are approved for use on food crops. A similar fungus, *Metarhizium anisopliae*, causes high mortality of PC larvae in lab assays (Whalon, unpublished), but the only strain registered with EPA (in a granular formulation) is not currently approved for use on food crops. Swiss and Austrian companies are currently marketing *Beauveria* spp. and *M. anisopliae* on barley kernels for control mainly of European Cockchafer in pasture. A clay granule formulation for corn earworm is available in France. However, there is no availability of an alternative formulation, in particular grain-matrix formulations, labeled for use on food crops in the US. Preliminary research conducted in Michigan has demonstrated some promise for PC control. It is unknown whether soil management of PC can effect economic control. No research has been conducted in Michigan to date on control of CFF.

iv. Pipeline

The USDA and state agricultural experiment stations Interregional Research Project Number 4 (IR-4) helps minor acreage specialty crop producers obtain EPA tolerances and new registered uses for pest control products in a process referred to as the pipeline. We anticipate that the availability of new insecticides that have strong activity against PC and CFF will be critical to the tart cherry industry's ability to meet zero tolerance for wormy fruit in coming years. The recent registrations of some new insecticides for use in fruit production systems, especially apple, are encouraging. The USEPA has granted most of them the status of "reduced-risk" or "OP-replacement." All of these new insecticides have a relatively narrow spectrum of pest activity, and their primary targets have been lepidopteran or soft-bodied pest species. In addition, even though these novel compounds provide encouraging levels of fruit protection, their activity on the target pests appears to be very different than that of conventional compounds. In contrast to broad-spectrum OP insecticides which are fast acting and highly lethal to all arthropods, some of these new insecticide chemistries are generally weak contact poisons and produce an array of sub-lethal effects (Liburd *et al*., 2003). Robust efficacy testing, both in small-plots and on-farm, are needed to support these registrations and increase grower willingness to risk their crop to these novel insecticides. The situation of increased PC and CFF pressure to the tart cherry industry dictates an all out response against all susceptible life stages of the PC, particularly those life stages not previously targeted by the powerful OPs and not controllable when targeted by the only available alternatives. Thus new strategies, tactics and tools are needed right now to help replace azinphosmethyl.

•*Clothianidin* (Clutch®) – IRAC MOA class 4A: Neonicotinoids
Control of PC is good, and Clutch® shows rapid and residual activity by contact and through ingestion.

•*Thiacloprid* (Calypso®) – IRAC MOA class 4A: Neonicotinoids
Calypso® provides good to excellent control of PC in apples, but it is not yet registered for use in cherries. The primary route of entry into the target pest is ingestion. Preliminary data from CFF trials are promising, showing good fruit protection in small plot trials in Utah (Alston, 2002). However, a lack of efficacy data has slowed further development and registration of this promising compound for use in cherries. Also, it has a 30-day PHI in apples, which is a concern for control close to harvest, when CFF are most active.

•*Pyriproxyfen* (Esteem®) – IRAC MOA class 7C: Pyriproxyfen
Esteem® is an insect growth regulator (IGR) that exhibits juvenoid activity of disrupting normal hormonal balance of insects. Such activity adversely affects physiological processes fundamental to the normal growth and development of insects. Application of pyriporxyfen to the chrysomelid beetle, *Aulacophora nigripennis* (Motschulsky), terminated diapauses and inhibited the accumulation of the cryoprotectant myo-inositol, considered necessary energy source for overwintering process (Watanabe, 1998). Similarly in PC, laboratory bioassay has demonstrated that pyriproxyfen breaks obligate winter reproductive diapauses in northern strain plum curculio female adults (Hoffmann 2007). These studies suggest that the induction of plum curculio mating behavior prior to overwintering may interfere with the necessary physiological and behavioral preparations for the colder months, and late-season application of pyriporyxfen in the field could reduce the number of plum curculio adults that successfully overwinter and may result in population reduction overtime. Laboratory assays and initial small-scale field tests have shown a high success rate in causing and maintaining an effect, which would lead to death during the colder months (Kim *et al*., 2008, unpublished). Although Esteem looks promising for reducing overall population pressure, it will not be a stand alone strategy. There are concerns with potential impact on natural enemies. Effectiveness for CFF is unknown.

•*Novaluron* (Rimon®) – IRAC MOA class 15: Benzoylureas
This IGR is being developed for use against PC. Although still in the early stages of development, there have been promising results for this product (Whalon lab). Rimon® works as a chitin synthesis inhibitor by disrupting the formation of chitin during the

molting process or during egg development. However, the most remarkable results we have seen from this product are through vertical transmission, with no survival of larvae in lab studies. This occurs when the product enters the body of the adult female, but instead of being directly detrimental to the adult, it causes physiological disruption to the eggs (Wise et al. 2007). The result is that eggs are laid, but are essentially non-viable. This phenomena was also witnessed in other key pests as well (Cutler *et al*., 2005; Kostyokosky and Trostanetsky, 2006; Alyokhin *et al*., 2008). Early lab and small-scale field tests indicate a significant reduction in the number of larvae produced by eggs of females exposed to Rimon™. On farm trials have not begun even in 2008, as this product is not yet labeled for stone fruit (anticipated registration for 2008). Novaluron has proved to be as efficacious as an azinphosmethyl replacement (Wise *et al*., 2006a) for lepidopteran pests in apple and other fruit crops. The effects on CFF control are unknown, and there are also concerns with potential impacts on natural enemies, as well as residues at harvest.

•*Azadirachtin* (Neemix®) – IRAC MOA class 18B: Azadirachtin
Neemix® has shown poor control of PC. Apple maggot data in apples is comparable to cherry fruit fly data in cherries, and since apple maggot data has indicated poor to fair effectiveness, the likelyhood of effectiveness for CFF is comparably poor. Neem compounds have very short residual and are not rainfast.

•*Metaflumizone* (Alverde™) – IRAC MOA class 22B: Metaflumizone
Effectiveness of control for PC and CFF is unknown.

•*Flubendiamide* (Belt®) – IRAC MOA class 28: Anthranilic Diamides
This belongs to a new class of insecticides with a novel mode of action involving exploitation of the ryanodine receptor site and consequently the release of calcium ions (Nauen, 2006). Ryanodine receptor activators have primarily been tested for efficacy against lepidopteran pests. Their demonstrated high potency against key lepidopteran pests of tree fruit crops (Nauen 2006) have generated considerable excitement and accelerated the registrations timeline with commercial use anticipated in 2008 or 2009. However, effectiveness for control of CFF by this new class of insecticide is unknown.

•*Rynaxypyr* (Altacor®) – IRAC MOA class 28: Anthranilic Diamides
Effectiveness for control of CFF is unknown, but IR4 trials were conducted in Michigan in 2007. EPA registration is expected by 2009 possibly.

•*Entomopathogenic Nematodes (EPN)*
As part of the first RAMP, Diane Alston of Utah State University demonstrated the efficacy of entomopathogenic nematodes in substantially suppressing PC adult densities in fruit trees after two to three years of release (Alston, unpublished). The most efficacious EPN species tested was a population of *Heterorhabditis bacteriophora* trapped from soil in sites infested with plum curculio. Laboratory studies on the influence of temperature range on infection, establishment and insect host mortality found that this population of *H. bacteriophora* is well adapted to the soil temperature range encountered by plum curculio larvae in the field (15-30ºC). Reproduction rate and total production exceeded several other nematode species tested by two to three times. EPN attack the larval stage in the soil upon leaving the fruit. Entomopathogenic nematodes as a biocide for plum curculio can significantly reduce populations when used on a meso-scale in the landscape and applied to multiple locations that target susceptible life stages of plum curculio, and when applied over a period of several seasons.

Entomopathogenic nematodes show a good fit as an important population suppressant of plum curculio that will allow reduced toxicity and sustainable insecticide programs to maintain densities below economic thresholds. This approach would be following the same philosophy used in area-wide mating disruption programs for codling moth where mating disruption lowers the population enough to allow use of softer supplemental tactics. It is unknown however whether soil management of PC can effect economic control and zero tolerance policy standards. Preliminary data in WA shows EPN to be effective predators of CFF. However, EPN do not prevent immigrant gravid female flies from flying into the orchard and laying eggs. Most likely, EPN will just be part of a comprehensive IPM program.

•*Pesticide-treated biodegradable spheres*

These provide an attract and kill tactic. Preliminary data in apples indicates fair control of apple maggot, but pesticide-treated biodegradable spheres have not been tested for CFF. They are likely to be ineffective for CFF, but have the potential to reduce the number of necessary sprays of other chemistries.

v. Other Pest Management Aids

There are several other practices that are used in an integrated program for pest control. Established orchard monitoring programs have already significantly reduced organophosphate applications. Alternate row spraying is now a frequently practiced method of application for AZM to reduce grower costs, fuel use, and worker exposure. Incorporating possible alternate-row spraying and border spraying of alternative insecticides could reduce the number of sprays while maintaining coverage of the entire orchard. Also, ethephon is applied as a cherry loosener to help harvest with mechanical shakers, which is not only economical, but dramatically reduces worker exposure to pesticides. In the Upper Midwest, 98% of growers use ethephon (Whalon *et al*., 1982). It is critical to harvest as much fruit as possible, to decrease the amount of crop available for post harvest infestations. Similarly, removal of abandon orchards and other alternative hosts can lower the chance of attracting pests.

In an effort to move away from AZM, cherry growers must spray post-harvest to control PC and CFF (Table 1). Use of post-harvest sprays in AZM-alternative blocks for PC and CFF greatly increases cost, worker exposure, and ecological and environmental impacts. This practice will not only extend the spray season, but will indirectly impact beneficial and likely accelerate resistance development to Neonicotinoids and IGRs.

B. Research & Implementation

i. Research Needs

US tart cherry growers are facing the challenges of pest management resulting from increasing regulatory constrains during the phase-out process. A previously funded tart cherry USDA RAMP grant provided solid evidence of OP-alternative failure to prevent wormy fruit at harvest, increased cost of OP-alternative and reduced risk spray programs, and resistance of cherry leaf spot to traditional fungicides. To address these challenges, a RAMP II project was developed. This second project has an intense focus on identifying new effective pesticides, developing and implementing promising biopesticides, post-harvest control strategies, and landscape level IPM management approaches.

The RAMP II project has three different base program spray plans, along with an array of possible alternative spray plans. The project will focus on the ability to effectively control five main target pests: plum curculio, cherry fruit fly, borers, OBLR, and GFW. In addition to this, other considerations will be monitored in each participating orchard, including mite outbreaks, Lepidoptera populations, rebound pests (such as aphids), the overall cost effectiveness, and functional ecology. Along with these planned spray programs and targets, there are still questions remaining. These include recommended miticides, possible borer strategies, and post harvest decisions.

The overall mission of this RAMP II project is to revolutionize the US tart cherry industry by facilitating public and private collaborative IPM implementation that will ensure accountability in environmental quality, grower and processor profitability, ecological sustainability and rapid adoption of landscape level, bio-based IPM systems while maintaining and strengthening the US tart cherry industry's current preeminent position against mounting foreign competition.

Apart from the RAMP II research, additional research will direct an intense focus towards biopesticides and phenology model timing of OP-alternatives. For newer chemistries that are not broad target like AZM, such as IGRs, neonicotinoids, and biopesticides, growers will need to precisely time applications with the emergence of the targeted stage of development for a given pest. Without the development of this delivery system, these new pest management tools will be of little use to growers since previous research demonstrates that standard calendar spraying results in poor timing and the loss of efficacy, along with the waste of money and unnecessary environmental and ecological impact.

ii. Infrastructure needs

Michigan is a leader in specialty crop production, currently number one nationally in the production of tart cherries and blueberries, and number three in apples. In the last decade the FDA has reordered fruits and vegetables as to their importance for human dietary intake as well as their place in the Food Pyramid. Fruit crops in particular are receiving heightened attention for their health benefits. Despite the benefits for the consumer, specialty crop production is a high-risk endeavor. Fruit crops in particular have exceptionally high market standards for fresh ad processed products (particularly cherries with the zero tolerance policy), and crop production requires considerable knowledge and skills in the areas of horticulture and pest management. The result is a situation where there is very little room for error in specialty crop production to attain the expected high quality, blemish-free end product. This AZM phase-out further amplifies the risks in specialty crop production. Even with the "fast-track" of registration of many new reduced-risk pesticides, there is still a need to enhanced knowledge of the pests, crop, and environment to achieve optimal performance. Increased knowledge in these areas will also allow for the development of more comprehensive IPM systems.

C. Regulatory issues

In addition to the currently registered OP-alternative and reduced-risk compounds, there are several chemistries and alternative control materials currently in the

IR4 pipeline. Recent research indicates that new insecticides in the neonicotinoid, IGR, oxidiazine and spinosyn classes have the potential to be important contributors to the fruit IPM arsenal, but that they are different than conventional insecticides in many ways (Isaacs *et al*. 2004, Wise *et al*. 2006a). Unregistered compounds, which exhibit possible effectiveness for use in tart cherry production in preliminary studies, are processed in the IR4 pipeline (*See* II.A.iv.Pipeline *above*). Facilitation and engagement of the IR-4 Pesticide Clearance Report process to accelerate registration of candidate OP replacements is critical to streamline the registrations for reduced risk and organophosphate alternative compounds.

D. Trade issues

With the passage of the FQPA, the pre-harvest interval of AZM was extended to protect against residues in the diets of children and infants, even though OP residues were well below tolerance levels, and usually below the limit of detection in processed cherries (see Tables 2 and 3 above). Maximum level residues (MRLs) are regulated by the US and many other countries. However, not all countries require MRLs, and they are not on a consistent scale. The company that produces Assail® will not even fund the research to determine MRLs for its product (*See* II.A.ii.Acetamiprid *above*). MRLs for several countries are shown in Table 6.

It is difficult for members of the tart cherry industry to stay competitive in ever-increasing global competition. For example, Poland's cherry industry has very few OP restrictions and standard US and Polish water handling of harvested cherries removes residues below the limit of detection even after high OP use (Bennett et al. 2000). In 2002, Poland exported 19 million pounds of red tart cherries to the US, up from 5 million pounds in 2001 (US Customs Census 2002). Recent figures are very difficult to obtain, because imported product from Poland, Yugoslavia, Romania and Germany come into the US not only as frozen or canned processed cherry products but also in finished foods like candies, frozen tarts, glazes, pastries or neutriceutical health foods. Given the escalating competition, fueled by US pesticide regulations, it is not surprising that tart cherry stakeholders have identified management of PC and CFF as their top research priorities in both the 2001 and 2006 Tart Cherry Pest Management Strategic Plan (PMSP, 2000).

Tart cherries, even among other competing US fruits, are at a serious disadvantage not only in the US but from mounting global competition, where OP's are increasing in use, but will not be curtailed by the US's FQPA sanctions. In addition, urban encroachment and rural sprawl (Pijanowski et al. 2002), together with water-related environmental scrutiny (MI Dept. of Agriculture and the Dept. of Environmental Quality, together with USEPA 1998) in the beautiful landscapes where cherries are typically grown along the Great Lakes provide ample further challenges to the resiliency of the US tart cherry industry.

Table 6. MRLs for various countries, compiled by the Pesticide Program Dialogue Committee, 2007

Chemical	U.S. Regulatory Status	International Regulatory status [Key Export Markets]					
		Canada	*Mexico*	*CODEX*	*Japan*	*EU*	*Other MRLs*
Thiacloprid	0.3	0.3	0.3	None listed			None listed in: Taiwan, Hong Kong, Malaysia
Imidacloprid	3	3	3	0.5	3	0.5	Australia (0.5), None listed in: Taiwan, UK
Phosmet	10	7		10	0.1	2 (UK)	Taiwan (2), Australia (1)
Spinosad	0.2	0.2 [proposed]		0.2	0.2		UK (0.2), Australia (1), None listed in Taiwan
Thiamethoxam	0.5	0.02 [import]		None listed	5		None listed in: Taiwan, UK, Australia
Acetamiprid	1	1 [proposed]	1	None listed			None listed in: Brazil, Sweden, Russia

E. Impact Assessment

i. Economics

A first cut in measuring the economic impact of switching pesticide control programs is provided by comparison of average cost of spray materials applied by participating growers. The RAMP I study found that spray programs using reduced-risk and OP-alternative compounds (referred to in this section as *Alternative*) cost more than conventional spray programs. In 2007, the average cost of spray materials for nine MI growers was $82.63 for alternative orchards, versus only $47.02 for conventional orchards. In part though, this is reflective of the different growing conditions among individual blocks within the crop year (Table 7.)

A switch in spray program also impacts grower costs when the number of applications and/or amount of scouting required changes. Anecdotally growers have reported increased scouting. Changes in the number of applications varies more widely as tank-mixing of spray materials is common. A base enterprise budget for tart cherry production in three Michigan growing regions (Northwest, West Central, and Southwest) under conventional practices has been constructed and will be used to estimate changes in these additional costs when spray programs are changed.

In Table 7, growers in 2007 sprayed an average 4.38 times in alternative blocks compared to 5.27 times in the conventional blocks. The range in number of insecticide applications was slightly higher in conventional orchards (2.5 to 9 sprays) compared to (2.5 to 8 sprays). As already shown above, average materiel costs in alternative blocks are higher than those in conventional blocks; the same pattern holds for minimum and maximum material costs. Figure 12 compares total dollars spent by all participating growers on spray products used in alternative versus conventional programs during 2007. While Lorsban®, Guthion® and Imidan® represent the highest percentage of total cost in conventional blocks; Provado®, Actara®, and Nexter® contribute the most to pesticide expenditures in the alternative blocks.

Table 7. Estimated pesticide input costs, reduced-risk and OP-alternative versus conventional blocks, 2007

	Alternative			**Conventional (AZM)**		
	Average	Max	Min	Average	Max	Min
# of spray applications	4.38	8	2.5	5.27	9	2.5
material cost ($/acre)	85.39	126.58	44.19	47.02	69.18	31.55
difference in material cost*	38.37	57.40	12.64	-----	-----	-----

* Does not include cost of application or spray materials other than insecticides. Includes miticide costs, but not sulfur.

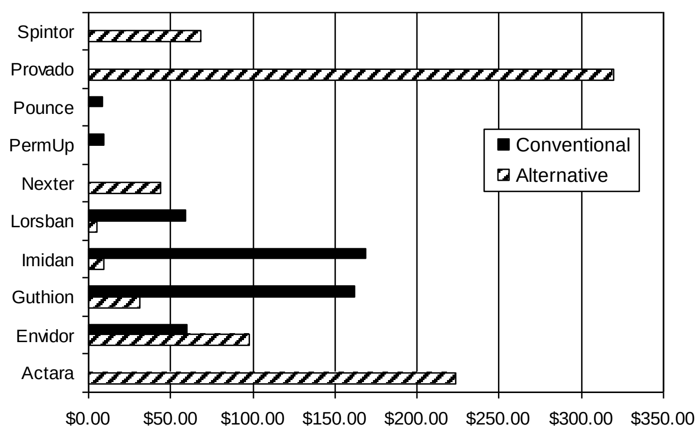


Figure 12. Total insecticide cost by chemical in 2007
N.B. the costs inside the graph represent the total cost across all growers for the alternative and conventional (AZM) blocks.

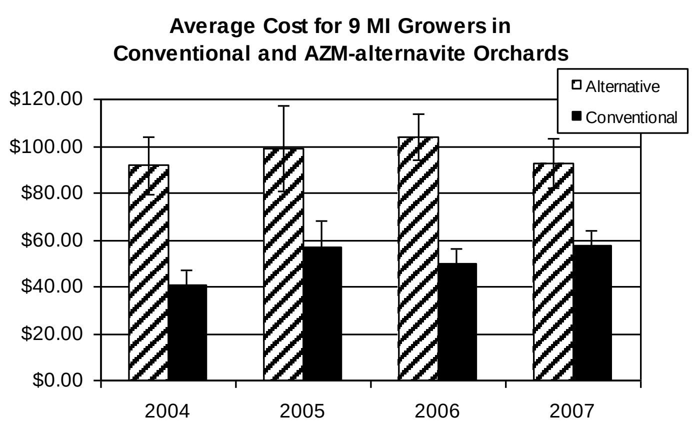


Figure 13. Average cost of insecticides used in reduced-risk/OP-alternative and conventional orchards. Only includes insecticide and miticide costs.

ii. Field impacts

With many of the AZM alternatives, growers are forced to use a greater number of sprays to achieve the same effective control of pests. With newer chemistries, there is a greater uncertainty in the effectiveness of pest control, along with greater uncertainty in the ability to maintain the zero tolerance policy standards. If reduced risk and OP alternative compounds cannot achieve this standard, then there will be greater rejected loads, resulting in severely detrimental economic consequences for growers.

Table 8 also compares total costs (by all participating growers) on alternative insecticide products in the alternative and conventional spray programs. In the alternative program expenditures on Provado®, Actara®, Spintor® and Nexter® account for over 80% of the total (Envidor® is used in conventional plots as well as alternative). These products are not a part of the traditional program where expenditures on Guthion®, Lorsban®, and Imidan® account for approximately 83% of the total.

Table 8. Percentage of each product cost in the total cost of pesticide sprayed in 2007

	AZM-Alternative		**Conventional**	
Product	Total ($)	Share (%)	Total ($)	Share (%)
Actara	$223.68	27.99	$0.00	0.00
Envidor	$97.99	12.26	$59.75	12.80
Guthion	$31.54	3.95	$161.62	34.61
Imidan	$8.90	1.11	$169.08	36.21
Lorsban	$5.25	0.66	$59.42	12.72
Nexter	$43.56	5.45	$0.00	0.00
PermUp	$0.00	0.00	$8.88	1.90
Pounce	$0.00	0.00	$8.21	1.76
Provado	$319.83	40.03	$0.00	0.00
Spintor	$68.27	8.54	$0.00	0.00

F. Other barriers to adoption

The complexity of transitioning away from AZM poses a large barrier for grower adoption of reduced-risk and OP-alternative spray regimes. With AZM, there was an established third-level IPM program, including GFW, PC, and CFF monitoring. A transition to neonicotinoids, oxidizers, IGRs and miticides will reduce the IPM program back to first-level monitoring; little more than calendar sprays. Thresholds and timing will have to be reestablished for any new programs, which takes several years to determine and fine-tune. (*See* I.A.v *above*).

III. Identify metrics and milestones for transition.

A. Tasks and timelines

Table 9. Steps toward the development and implementation of reduced-risk and organophosphate-alternative management systems for plum curculio and cherry fruit fly

Product Steps	**Verification**	**Timeline**
1. Implement insect monitoring systems	Weekly monitoring records	Apr 2008 –Aug 2010
2. Implement on-farm reduced risk spray programs for PC and CFF	Grower spray records, damage assessments, monitoring records	April 2008 – August 2010

3. Perform insecticide efficacy trials on MSU research farms for PC and CFF	Weekly monitoring records, Spray, trapping and damage records	April 2008 – August 2010
4. Develop and implement post harvest PC and CFF control strategies	Post harvest, spring monitoring and trapping records, phenology model refinement	April 2008 – August 2010
5. Work with IR-4 pesticide clearance report process to speed registration	New chemistries ID'ed, registered	Fall 2008 – August 2010
6. Fulfillment of the objective	Implementation of efficacious, reduced-risk & OP alternative insect control, survey results	Fall 2010

Table 10. Steps toward the development and implementation of meso-scale landscape management to reduce PC and CFF population densities

Product Steps	Verification	Timeline
1. Test nematodes in orchard surrounding habitats	Emergence trap data, return populations	June 2008-August 2010
2. Assess PC population suppression by applied *Metarhizium*, *Beauveria* and nematodes	Mortality record of adult emergence from treated soils, statistical analyses	June 2008-Aug. 2010
3. Determine persistence of entomopathogenic fungi in soil	Results from testing soils against PC larvae in lab	April 2008- Fall 2010
4. Assess effects of entomopathogen applications to beneficial soil arthropod populations	Pitfall trap catch community analysis	April 2008 – Oct. 2010
5. Fulfillment of the objective	Integrate biopesticide methods into PC and CFF management	December 2010

Table 11. Steps toward the development and implementation of ecological impact assessment tools to measure changes in ecosystem services

Product Steps	Verification	Timeline
1. Develop "master index" incorporating soil microbial diversity, carbon assimilation, natural enemy and leafroller diversity	Delivery of master index	April 2008-August 2009
2. Educate crop consultants on use of master index	Meeting attendance, presentations	Fall 2009-Spring 2010
3. Implementation of on-farm, consultant driven ecosystem assessments	Ecosystem assessment data	April 2010-August 2010
4. Develop functional ecology field guide for lepidopteran diversity ID	Guide publication	June 2010

Table 12. Steps towards conducting a sociological evaluation of the newly implemented system

Product Steps	Verification	Timeline
1. Compare follow-up surveys in years 2 and 3 with 2003 baseline survey to document change & test for statistical significance.	Report of results	Fall 2008-2010
2. Create and distribute Biannual Newsletters to national CMI mailing list to inform of project activities and results.	Project newsletter	Winter 2007 – Fall 2010
3. Identify key grower meetings in each state and deliver activities/presentations that address identified barriers to adopting IPM, & provide project updates.	activities/presentations	Winter 2007 - 2010

4. Participate in Michigan Tart Cherry Think Tank session (approximately 50 participants); introduce the project and present results from baseline survey.	Meeting minutes	Spring 2004
5. Provide real-time information about IPM strategies in MSU CAT Alerts, Code-A-Phone, and weekly grower meetings in each state.	MSU CAT Alert newsletters Code-a-phone logs Grower meeting participation Telephone logs	Spring and Summer 2004 -2007
8. Attend and present at special symposium in WI and UT	Symposium minutes	Winter 2005
9. Participate annually in MSU IPM Fruit School; update scouts and growers on project research and key implementation tools & tactics	MSU IPM Fruit School records	February 2004 – 2008
10. Results from previously funded tart cherry RAMP presented to growers & their feedback collected.	Presentations & meeting summaries	Fall 2008
11. Management team discusses and refines IPM model	Meeting summary; refined model	Winter 2008-09
12. Three to four growers in each state pilot test the project evaluation survey	Pilot test results	Winter 2009
13. Surveys sent to growers in all 3 project states	Final survey & production costs (reproduction & postage)	Winter 2009
14. At least 50% of growers return completed surveys	Survey results	Winter-Spring 2009
15. Survey data analyzed and presented to management team	Report & meeting minutes	Fall-Winter 2009
16. Results from surveys are incorporated into Outreach & Extension efforts	Outreach & Extension activities	Spring/Summer 2009-10
17. Economic data analysis performed annually	Written analyses, final report	Fall 2007-Fall 2010
18. Final project survey conducted	Report of results	Winter 2010
19. Analysis of IPM adoption completed	Report of results	Summer 2010
20. Completion of the objective	All of the above	Fall-Winter 2010

Table 13. Summary of key insecticide activities against plum curculio [a]

Compound	Trade Name	Class	Reduced Risk	OP Alternative	Lab		Field			
					Egg LC_{50} ppm	Larval toxicity EC (ppm)[b]	Larval emergence (relative to untreated)	Emerged Larval Mass Difference?	Larvae still in fruit after 30d	Difference in Larval mass in fruit
Azinphos-methyl	Guthion®	Organophosphate	NO	NO	0.4	1.0	0	-	NO	-
Phosmet	Imidan®	Organophosphate	NO	NO	2.1	1.0	7%	NO	NO	NO
Acetamiprid	Assail®	Neonicotinoid	YES	YES	>100	1.0 [c] 0.1	0-24%	NO	NO	NO
Thiamethoxam	Actara®	Neonicotinoid	NO	YES	>100	0.1 [c]	<5%	YES, smaller	NO	NO
Thiacloprid	Calypso™	Neonicotinoid	YES	YES	58	0.1	2-20%	NO	NO	NO
Clothianidin	Clutch™	Neonicotinoid	YES	YES	33	NA	NA	NA	NA	NA
Indoxacarb	Avaunt®	Oxadiazine	YES	YES	>100	>1.0	25-50%	NO	NO	NO
Esfenvalerate	Asana®	Pyrethroid (T-II)	NO	NO	0.5	0.1 [c]	>75%	NO	NO	NO
Chlorantraniliprole	Altacor	Anthranilic Diamide	YES [d]	YES [d]	>100	NA	60%	No	NO	NO
Pyriproxyfen	Esteem®	IGR: JH mimic	YES	YES	>100	>1.0	>50%	YES- larger	YES > 8x normal rate	Yes, larger
Novaluron	Rimon®	IGR: Chitin Synth Inihib.	YES	YES	0.4	1.0 [c] 0.25	>60%	NO	NO	NO

[a.] Source: Hoffmann, EJ. 2008. Identification & characterization of key insecticide performance mechanisms for the control of plum curculio (*Conotrachelus nenuphar*) in Michigan tart cherries. Ph.D. Dissertation, Department of Entomology, Michigan State University,
[b.] < 10% survivors
[c.] No survivors at this rate
[d.] Registration pending

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