

Project Summary/Abstract

Project Title: Development of advanced integrated pest management for Northeastern apples.
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(i) Project Type: Joint Research-Extension

Requested funds:

Research (PL89-106): \$133,093

Extension (Smith-Lever): \$31,532

(ii) Summary Statement:

A partnership among land-grant and USDA researchers, Extension and growers, has brought a unique skill set into development of an advanced integrated pest management (IPM) protocol for apples. The collaborators, including several growers, have worked on development of individual components of this system over recent years. The unique aspect of this project is it brings the most promising of these tactics together in a single management system. While the vast majority of apple growers in the Northeast use IPM tactics, progress in reducing toxic chemical inputs has stalled in recent years. The proposed system will introduce advanced IPM tactics that eliminate use of organophosphate pesticides, minimize the use of pesticides in general, and moves towards practical bio-intensive alternatives. The most important apple pests, including plum curculio, apple maggot, leafrollers and internal Lepidoptera, apple scab and the sooty blotch/flyspeck disease complex, will be addressed. The project also stretches beyond pest management per se to test alternative fruit thinning methods that will eliminate use of a carbamate pesticide. Because researchers in the project also have Extension appointments or significant experience with Extension, and have developed on-farm research and demonstration collaborations with growers, successful tactics will rapidly move into commercial use. Web-based communication will facilitate research and will provide collaborating growers and eventually the industry in general with access to ways to implement advanced IPM. Traditional Extension methods, including widely read newsletters and journals, well-attended meetings, and on-farm demonstrations will insure broad industry awareness of the program.

TITLE**Development of Advanced Integrated Pest Management for Northeastern Apples****PROJECT NARRATIVE****(i) Problem, Background and Justification**

Apples are a high value crop in the Northeast, with an annual farm-gate value of \$389 million in 2006, and a value of \$200 million in New York and New England alone (USDA, 2007). Nearly 100,000 acres are devoted to apples in the Northeast. Apples in the Northeast are attacked by dozens of pests, both arthropods and diseases, but a relatively small group generates the most pesticide use. There is a long and productive history of apple IPM research and implementation in the region, most growers now use some form of IPM, and both private and public consultants support their efforts. There is evidence that in spite of IPM, pesticide use on apples in the region has not decreased significantly in recent years, and may be increasing. This trend is the result of several factors, including regulation of older pesticides, resistance to pesticides, increased global competition, and increased labor costs associated with some IPM tactics (Cooley, 2008). In addition, newer pesticides are more expensive and require more sophisticated, precise application patterns because they often have narrower spectrums of activity and different modes of activity. For apple IPM to progress towards a goal of economically and ecologically sustainable production, new tactics addressing these issues will have to be developed.

Key Pests. The most important insect problems faced by Northeastern growers come from species whose larvae feed internally within fruit (internal feeders). This insect complex includes the codling moth (CM), *Cydia pomonella*, oriental fruit moth (OFM), *Grapholita molesta*, apple maggot (AM), *Rhagoletis pomonella*, and plum curculio (PC), *Conotrachelus nenuphar*. In addition, a key leafroller species, the obliquebanded leafroller (OBLR), *Choristoneura rosaceana*, also feeds directly on fruit and can cause major crop losses.

In a recent survey of commercial apple growers in New England, the plum curculio was identified as the pest that required the greatest pest management effort (Clifton, 2005). Growers typically apply three insecticide treatments to manage plum curculio in Northeastern apple orchards (Prokopy *et al.*, 1996; Reissig *et al.*, 1998). The apple maggot fly typically requires three whole-orchard insecticide treatments (Prokopy *et al.*, 1990). Organophosphate insecticides (OPs) are the most common and cost-effective treatment option, and treatments targeting apple maggot fly (applied July-August) are the most prevalent source of detectable OP residues on harvested fruit (Wright *et al.*, 1998). The OBLR is a serious pest in many orchards in western NY and outbreaks of this pest have also begun to occur in other apple production regions in NY and in New England. Growers normally apply several insecticide sprays during the summer to control OBLR and only several insecticides are still effective against this pest because it is resistant to the organophosphates and several other classes of insecticides (Reissig and Combs, 2007)

The primary disease problem in the region, and in the world, is apple scab, caused by the fungus *Venturia inaequalis*. This disease drives fungicide applications in the first part of the growing season, and if uncontrolled, it will continue to require treatment to harvest. In addition, fungicide applications in the latter part of the growing season are driven by a complex of summer blemish

diseases, including flyspeck caused by *Schizothyrium pomi*, and sooty blotch caused by several fungi (*Peltaster fructicola*, *Leptodontidium elatius*, and *Geastrumia polystigmatis*). Summer disease pathogens grow on the surface of apples, causing blemishes that reduce visual appeal. The complex (SBFS) is treated as one disease.

Another pesticide-related issue has received less attention from pest management specialists: fruit thinning. Fruit thinning is a practice used to increase fruit size and insure annual production. To obtain larger, more profitable apple fruit, and to enhance flower bud formation for the next growing season, apple growers use chemicals to remove many developing fruitlets from trees. One to three applications of these chemicals may be made, beginning and bloom and continuing for approximately 3 to 4 weeks after pollination. Most thinning chemicals are hormone analogs or affect hormone concentrations. Carbaryl (Sevin®), however, is an insecticide but is also active as a chemical thinning agent. It has been studied thoroughly, used for many years, and is an integral part of nearly all university-based thinning recommendations and fruit growers' thinning programs. It is most often used in combination with other chemical thinners, providing a synergistic increase in thinning effectiveness.

Some alternative approaches to chemical thinning target the blossoms, making them unable to be pollinated. A combination of oil and lime sulfur can provide blossom thinning, and it has received some research attention as an acceptable organic approach. Further, ammonium thiosulfate (ATS), a foliar fertilizer, can also thin blossoms. Both of these treatments provide a similar thinning effect by simply damaging the flower. The difficulty with their use comes from the need to time application after enough flowers have been pollinated to provide a good crop but before so many are pollinated that significant thinning is required.

Pesticide Issues. OP's have been the cornerstone of apple insect management programs for 40 years, but the Environmental Protection Agency (EPA) has reduced the amount of annual azinphosmethyl use and increased worker re-entry intervals in azinphosmethyl-treated orchards, and will ban all use of the product by 2012. Additionally, chlorpyrifos was restricted to prebloom use in apples, and the amount of phosmet allowed per season has been restricted. Clearly, the future availability of OP insecticides for use on apples is questionable. In addition, both the carbamate and pyrethroid insecticides are undergoing the rigors of the mandated Food Quality Protection Act review. Uses of the carbamate insecticide carbaryl have been restricted or voluntarily dropped by registrants following recent EPA review (EPA, 2007), though it remains the most broadly used thinning agent on apples in the Northeast.

Fungicide use on apples in the U.S. is relatively heavy, exceeding that in almost all other food crops (Gianessi and Marcelli, 2000). Many fungicides that are critical to control of apple diseases have been classified as probable human carcinogens including the EBDC's, the dithiocarbamates, and captan (EPA, 1999; EPA, 2005). One national usage estimate (Felsot, 1998) indicates that these fungicides make up 58% of the total fungicides applied to apples, and that approximately half the apple acreage in the U.S. receives EBDCs or captan.

Use of pesticides in apples has raised consumer concerns. Reports issued by Consumers Union (Groth *et al.*, 1999) and the Environmental Working Group (Wiles *et al.*, 1999) have both targeted apples and called for the elimination of certain organophosphate (OP) insecticides and

carbamates. The Environmental Working Group has also pointed out problems with the ethylene-bis-dithiocarbamates (EBDCs) fungicides and captan (Hettenbach and Wiles, 2000).

While regulators and consumers have been applying pressure to limit use of older pesticides, apple growers have few alternatives. For example, *V. inaequalis* resistance to fungicides has become a significant problem in apple the Northeast. Fungal pathogens have developed resistance to both older fungicides, such as benomyl and dodine (Jones, 1981; Sutton, 1996; Yoshimura *et al.*, 2004), and to newer chemicals, such as the demethylation inhibitors (DMIs), strobilurins and anilinopyrimidines (Koller *et al.*, 2004; Köller *et al.*, 1997; Koller *et al.*, 2005 b; Holb and Schnabel, 2007). These same fungicides, particularly the DMIs, are far more effective than captan or the EBDCs when used as post-infection applications. DMI postinfection activity enabled development of scab management programs with intervals of 10 days or more between fungicide applications, a revolution in IPM (Wilcox *et al.*, 1992). However DMI resistance has led to increased fungicide use in recent years.

Traditionally, the key internal feeding worm species on apple in the Northeastern US, CM and OFM, were controlled by organophosphate insecticide sprays targeted against the PC and AM. However, in the mid- to late 1990's, OFM became a major problem for many apple growers in New York. Subsequent studies have shown that populations of OFM in apple orchards have become resistant to OP's, carbamates, and pyrethroids (Usmani and Shearer, 2001) More recently, outbreaks of CM in apple orchards have occurred in Michigan, New York, North Carolina and Pennsylvania, and studies have shown that populations in these areas have also developed resistance (2.5–7X) to OPs (Gut and Krawczyk, unpublished data).

Outbreaks of the OBLR first began to occur in commercial orchards in western NY in the mid 1970's, and subsequent studies have shown that these leafrollers have become resistant to all OPs registered on apples, and to many carbamates and synthetic pyrethroids (Reissig *et al.*, 1986). Fortunately, these species can still be controlled by other types of insecticides, including newer reduced-risk materials such as tebufenozide, spinosad, emmectin benzoate, spinotaram, and Rynaxpyr (Reissig and Agnello, 2008; Reissig and Combs, 2007; Waldstein and Reissig, 2001). However, it is essential to minimize selection pressure imposed on OBLR by these compounds, to prevent further resistance development (Reissig *et al.*, 2007).

In general, newer pesticides are more expensive than older materials. Recent studies conducted in apple production regions in the Northeast have shown that seasonal management programs of new insecticides are more expensive than older, conventional materials. A 4-year USDA RAMP project started in 2002 to evaluate reduced risk insecticides in apple and peach IPM systems in the eastern U.S. insecticides showed that programs using these materials plus mating disruption were substantially more expensive (2.5X) than growers' standard programs using only conventional insecticides. Furthermore, while RR insecticides alone, without mating disruption, did control internal Lepidoptera and other arthropod pests, these programs were still more expensive (1.5X) than conventional programs. For instance, in NY, average per-acre insecticide costs ranged from \$216 to \$262 in RR blocks, compared with \$149 to \$202 in conventional blocks (Agnello, Reissig, and Nyrop, unpublished data).

Apple growers in the Eastern US who are trying to manage pest resistance, and introduce newer pesticides into IPM programs are currently faced with a dilemma: the older pesticides that formerly worked the most consistently, were easy to use and cost the least now are losing

effectiveness because of pest resistance and present the most problems to regulators and consumers. Newer chemicals, where available, cost more, are often more difficult to use and may not be as effective as the materials they would replace.

One solution to this problem is to deemphasize chemical control in apple IPM programs, and substitute other types of tactics including biological controls, host genetics, and cultural practices. This idea has been formalized under the terms biointensive or advanced IPM (Benbrook, 1996; Dufour, 2001). Prokopy and others have observed that IPM develops along a continuum through increasingly complex levels (Prokopy, 1993). Apple IPM in the Northeast has reached a point that requires a move away from heavy reliance on chemicals, particularly more toxic chemicals, to a more balanced use of multiple tactics. **Without practical biointensive alternatives, apple growers will increasingly face regulatory and marketing issues that threaten their viability.**

Growers want better apple IPM tools. Growers recognize the need to make changes, and have identified many areas in which they would like to see research and Extension work. The objectives of this project meet several stakeholder needs, including those identified in the Northeast IPM Center Tree Fruit Working Group Priorities (NEIPM, 2003), the National IPM Road Map (RIPM, 2004) and the New England Apple Strategic Plan (NEPMN, 2003). Pertinent

Table 1. Selected needs identified for apple IPM and addressed in this proposal.

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Research	<ul style="list-style-type: none"> • Reduction of OP's and replacements; replacements for OP's, carbamates, pyrethroids • Development and testing of softer materials and non-pesticide options • OBLR management, OBLR-materials, timing, coverage • Apple scab ascospore maturity • Improve models and techniques that quantify and predict changes in scab risk potential • Apple scab sanitation methods need more study. • Develop predictive models for sooty blotch & flyspeck that are easy to use and applicable to New England conditions. • Better understanding of epidemiology of sooty blotch/flyspeck • Develop a site-specific risk assessment protocol to characterize individual orchards and the surrounding habitat as disease and/or apple maggot harborage • Verify effectiveness of insecticide-treated traps • Evaluate new pest management strategies including trap out. • Development and implementation of economical and effective IPM systems for crops and commodities consumed by humans • The priority in fruits is to develop alternative tactics that have major economic benefits and protect public health including workers and the environment.
Extension	<ul style="list-style-type: none"> • Education regarding monitoring techniques, economic thresholds, etc. • Education regarding use of limited-spectrum insecticides or alternative management strategies such as mating disruption as replacements for broad-spectrum materials and potential secondary effects. • Encourage use of IPM techniques through orchard demonstration plots. • Test and improve enhanced apple IPM website with participating growers.

needs from these publications are extracted and listed in Table 1. A Logic Model outlines the project below (page 12).

(ii) Objectives and Anticipated Impacts

Research objective

1. Develop appropriate, advanced IPM tools for key apple pests in the Northeast that will reduce pesticide use and allow the use of less toxic materials where pesticides are necessary.

- a. *Plum curculio* - use a trap tree approach to replace general orchard sprays.
- b. *Apple maggot* - use pesticide-treated sphere traps for management rather than general orchard sprays.
- c. *Obliquebanded leafrollers and internal Lepidoptera* - use seasonal fruit monitoring programs for optimizing insecticide treatments.
- d. *Eliminate OP's* and use pesticides with fewer non-target impacts.
- e. *Apple scab* - use potential ascospore dose, inoculum destruction and degree-day model to delay initial fungicide applications in the following season and end applications when unnecessary.
- f. *Sooty blotch and flyspeck* - develop model-directed applications of reduced-risk fungicides.
- g. *Enhance fruit thinning without the use of carbaryl* - develop effective approaches that do not use carbaryl as a thinning agent.

Extension objective

2. Promote adoption of advanced apple IPM methods through grower demonstrations, educational meetings and publications, and a web site.

This advanced IPM system will place growers in a position to sell to markets that demand and pay a premium for fruit grown using advanced IPM, including eco-marketing programs and integrated fruit production standards. In turn, this will enhance the economic viability of Northeastern apple growers while decreasing the environmental impacts of their production practices. Within the two-year time frame of this project, we anticipate relatively low-levels of adoption of one or more tactics, perhaps on the part of fewer than 2 to 5% of growers. However, within 5 years, we expect that 25% of New England growers and 10% of New York growers would adopt the system or some of its components, and this will continue to increase as regulations and consumer demand force growers to use fewer, softer pesticides.

Development and adoption of this advanced IPM program will have several impacts with respect to human health and economic benefits.

Safeguarding human health and the environment.

- Prophylactic sprays of pesticides will be eliminated.
- The use of higher risk pesticides, specifically OP's, carbamates, EBDC's and captan, will be reduced. (Specifics in **Pesticide Issues in Background**).

Economic benefits

- Decreases in cost due to decreased pesticide applications will probably be offset by increased management and pesticide costs, but will allow growers to access eco-markets and markets with stringent pesticide restrictions.
- The advanced system will require significantly more scouting and monitoring, and so will likely increase demand for IPM consulting services.
- Within three years, at least 50 growers in the region will have adopted all or some components of the advanced IPM system on all or part of their orchards. Adoption will continue to grow after that.

Implementation of IPM

- The project will test and demonstrate the system on 11 farms in New York and New England; tactics will be taught through meetings and web site to all growers in the region.
- In the second year of the project, the protocol will be available to all growers in the region and nationally via the web and published manual.

(iii) Approach and Procedures

1. Develop appropriate, advanced IPM tools for key apple pests in the Northeast that will reduce pesticide use and allow the use of less toxic materials where pesticides are necessary.

The collaborating growers have identified a block of trees of from 3 to 10 acres in each of their orchards that will be the “advanced IPM” block. This block will be used to test a combined system of advanced IPM tactics. The advanced IPM blocks will be visited every one to two weeks during the growing season by scientists and technicians in the project, who will assess the need for treatment and discuss treatments with each grower. Eleven growers in Connecticut, Maine, Massachusetts, New Hampshire, New York and Vermont have agreed to collaborate in this effort (see **Introduction, Program Staff, Apple Growers**). In each participating orchard, blocks that have been identified as “advanced IPM” will be paired with a comparative plot of similar size, location, and cultivar composition. This plot will serve as a grower-managed control plot; need and material for, and timing and rate of pesticide applications in these plots will be decided by individual growers.

In year 1, IPM recommendations will consist of tactics for each pest as described below. In some cases, i.e. for plum curculio, apple maggot and thinning, preliminary work will be done prior to incorporation of advanced tactics in the overall advanced IPM program. Other tactics will be tested in the advanced IPM block beginning in year 1. Thereafter, in year 2, based on results and on discussions between growers and IPM researchers, tactics may be modified. Pest damage results will consist of damage surveys at harvest, and where necessary at critical times in the growing season (e.g. the end of primary scab season and the end of curculio egg-laying). Pesticide use data will be maintained for both the advanced IPM plots and for the grower-managed control plots. Growers will use “TracApple” software or provide equivalent information to facilitate calculation of both costs and environmental impact ratings. Results will be summarized and presented to growers and other members of the advisory committee at an annual meeting in early March, in terms of economic and environmental comparisons with grower-managed controls.

During the season, participating growers will have access to an new enhanced tree fruit IPM website. This website is currently being developed by grants from the NEIPM program and the NY Farm Viability Institute. This website will provide developmental models of key insect and disease pests in real time throughout the season using weather data from the Cornell's Network for Environmental and Weather Awareness (NEWA) (NY-IPM, 2007). In addition the website will provide growers information about sampling and monitoring of pests at appropriate times and a support system to help them select the most appropriate pesticide when needed. Development of the site will begin in year 1, and a complete version will be available in year 2. Grower use of the site will be monitored, and annual assessments will be used to modify the site to better serve grower needs. The site will be available to all growers who wish to try the advanced IPM tactics.

Details for each objective are presented in the following sections. A timetable for the project is shown in Table 4 (below).

a. Plum curculio — trap tree. For management of plum curculio in the advanced IPM plot, we will evaluate the efficacy of the odor-baited trap tree strategy to control the immigrating population (Leskey *et al.*, 2008). For this trial, ~12 perimeter-row trees (based on a 5-acre experimental plot) will be baited with a synergistic odor blend for plum curculio, consisting of four dispensers of benzaldehyde and a single dispenser of grandisoic acid. These trap trees will be deployed ~25 meters from the ends of perimeter rows, and separated by ~50 meters within the perimeter row or row ends. At petal fall, each grower will apply a full-block insecticide treatment, using materials selected from the list of program-certified products. After petal fall, plum curculio will be managed in the advanced IPM plots using a trap-tree management protocol; only the odor-baited trap trees will be treated with insecticide following the full-block insecticide application at petal fall. Need and material for, and timing and rate of insecticide applications in the trap-tree plot will be left to the discretion of the participating grower, but all treatments after petal fall will be limited to odor-baited trap trees, reducing post-petal fall insecticide treatments by ~70%. In NY orchards during the initial year of the study, one half of the orchard perimeter will be treated with the trap trees and only these trees will be treated after petal fall as previously described. The other half of the perimeter row will be treated with border sprays as necessary after petal fall based on predictions from a PC oviposition model. If damage in the trap tree program and the perimeter spray treatments are comparable, the trap tree approach will be applied to the entire orchard perimeter during the second year of the study. The incidence of injury to fruit by PC in both the advanced IPM plot and grower control plot will be assessed ~8 weeks after the petal fall spray and again at harvest.

b. Apple maggot fly— pesticide-treated sphere trap. For apple maggot fly in the advanced IPM plot, we will assess the protective capability of odor-baited, toxicant-treated visual traps for direct control of apple maggot fly as a commercial substitute for summer insecticide sprays. In each of the advanced IPM plots, we will deploy a perimeter arrangement of odor-baited sphere traps to intercept and kill immigrating apple maggot flies; these test plots will receive no insecticide spray targeting apple maggot flies from mid-June through harvest. During the initial year of the study in NY, one half of the perimeter row will be treated with the toxicant traps and no control sprays will be applied for apple maggot control as previously described. The other half of the perimeter row in the plot will be monitored with volatile-baited sticky traps and

border sprays will be applied whenever catches exceed a treatment threshold of an average of 5 flies/trap. If AM damage at harvest is comparable in both plots after the first season, the entire border of the orchard will be treated with toxicant spheres during the second year of the study. As with the plum curculio trap-tree assessments, the paired, grower-managed plots will receive insecticide treatments based on individual growers' determination of need, timing, material, and rate. Both advanced IPM plots and grower-managed plots will be equipped with unbaited monitoring spheres within the body of the plot to monitor fly population density. Capture rates of apple maggot flies on these monitoring traps will be recorded biweekly. At harvest, we will evaluate fruit for the presence of apple maggot fly injury in plots protected by odor-baited visual traps and by conventional insecticide treatments.

c. Lepidoptera and obliquebanded leafrollers - seasonal fruit monitoring programs for optimizing insecticide treatments.

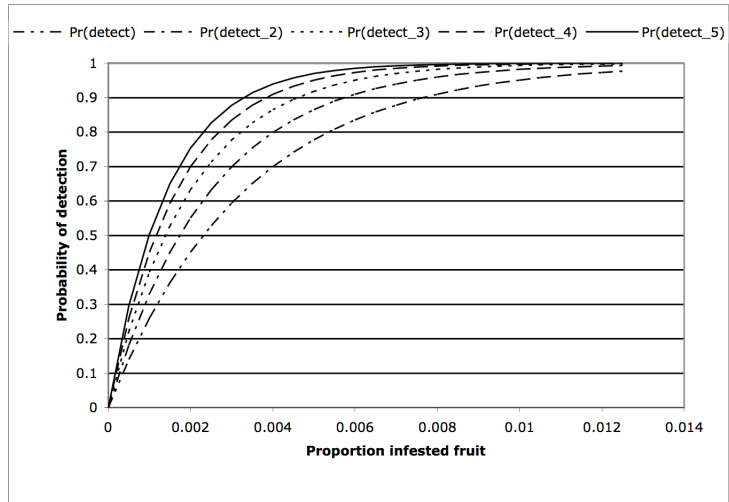
Obliquebanded leafroller. Treatments will be directed using a sampling system based on damaged fruit, rather than on growing terminals. In this system, starting at the predicted egg hatch date for summer generation larvae, 1000 apples will be sampled for OBLR damage weekly until late August. A control spray will be recommended when the first OBLR damaged fruit is observed. Then fruit will be sampled weekly and additional sprays will be recommended whenever fruit damage exceeds 1% of the apples sampled. Additional work will be done in this project to continue to test the effectiveness of this sampling scheme in preventing OBLR fruit damage, and to develop a faster sampling protocol similar to that currently utilized for sampling fruit for internal Lepidoptera, using sampling of small numbers of fruit more frequently to minimize the weekly sampling time.

Internal Lepidoptera. Many of the Northeast apple growers currently participating in the Eco-apple program have orchards that would be classified as "low" or "moderate" risk for infestations for the complex of internal Lepidoptera species in the region. This program will only be tested in blocks that have been classified in the "moderate risk" category.

The criterion for identifying a need for control is detection of one infested apple. This criterion is reasonable for at least four reasons: 1) Internal Lepidoptera infest fruit at relatively low levels so there is little difference between detection of an infestation and estimating the actual infestation rate, especially with the sample sizes we will use. 2) There is no established relationship between infestation rates at any particular point during the growing season and the need for control. 3) Tolerance for infestation is essentially nil. 4) Experience suggests that infestations do not occur along a smooth gradient from zero to some problematic level; rather, they seem to occur at relatively high levels or not at all. Given that detection of infestation is a reasonable decision criterion, a sampling strategy is required that minimizes the risk that a problematic infestation goes undetected. The complementary risk that detection occurs when none exists is not possible. Such a sampling strategy needs to satisfy two criteria; 1) It must allow for imprecision in the timing of sampling because the temporal patterns of infestations cannot be well predicted. 2) It must provide reasonable risk of error without excessive sample size. To meet these two needs we will sample fruit repeatedly through time with sample bouts occurring at weekly intervals.

To determine appropriate sample sizes, we calculated probabilities of seasonal detection of infestation after each successive sample bout using different sample sizes for each bout. Our proposed plan is to sample 300 fruits the first week after most of the eggs from the first generation of OFM have hatched and 100 fruits each subsequent week. Shown in the figure below are probabilities that an infestation will be detected given the true proportion of infested fruits for each week of a 5 week sampling period.

The figure (right) shows that after the first sample bout, the probability of detection is less than 0.8 for infestation levels below ca 0.5%. However, by the time the third sample is taken, this probability has risen to nearly 0.95. The same probability of detection could be achieved by sampling 500 fruits all at once; however this assumes that timing sampling can be done precisely, an assumption that is likely wrong.



This fruit sampling program can be used to determine when special control sprays are needed, but unless relatively large numbers of infested apples are detected so that larvae can be removed and identified, it will be difficult to determine which species may be responsible for damage. Therefore, pheromone trap catch patterns will be used to determine the choice of materials and timing of subsequent sprays against target species of internal Lepidoptera. After the season is over, the seasonal patterns of trap catch can also be used to compare predictions, at least for initial control sprays, based on pheromone trap catch thresholds or fruit sampling.

Insecticide Selection. Only newer, insecticides that are currently approved for use in the Eco-Apple Protocol developed by growers, scientists, and participating growers will be used in the research plots (Table 3). No organophosphates, carbamates or synthetic pyrethroids will be used. The insecticides shown in table three will also control other secondary pests such as leafhoppers and leafminers. Selective miticides such as clofentezine, abamectin, etoxazole, and pyridaben will be used whenever necessary to control mites. Imidacloprid will be used to control aphids.

Table 3. Newer insecticides and target direct fruit feeding insect pests.

Target Insect Pest	Insecticide
Plum Curculio	Indoxacarb, Thiamethoxam
Obliquebanded Leafroller	Spinatoram, emmemectin benzoate, Rynaxypr
Apple Maggot	Thiacloprid, Acetamiprid
Codling Moth, Oriental Fruit Moth	Spinatorum, Rynaxypr, Acetamiprid

d. Apple scab — ascospore dose-based fungicide applications. Foliar incidence of apple scab in each block will be assessed in the fall, after harvest. One hundred shoots will be sampled, with the number of shoots/tree varying with tree size according to established protocol (Cooley and Berkett, 2008). The total number of leaves with scab will be recorded, and the need for further sampling will be determined according to sequential sampling thresholds in the protocol. This also depends on whether sanitation methods to eradicate inoculum will be considered. When there is no need for further sampling, the potential ascospore dose (PAD) for the block will be determined.

Based on the PAD, the number of infection periods and/or the phenological growth stage at which scab fungicide applications should be started the following spring will be determined according to established thresholds (Reardon *et al.*, 2005). Growers will be advised when they should begin scab fungicides.

In blocks where sanitation will significantly decrease scab risk and enable growers to delay the first fungicide application, and growers have previously agreed to chop leaves and apply urea to eradicate scab inoculum, these procedures will be recommended. Sprays will be applied according to prediction of modified Mills infection periods, if existing fungicide protection is estimated to be inadequate due to new tissue growth or weathering (Gadoury *et al.*, 1989; Stensvand *et al.*, 1997).

A degree-day model has proven to give an accurate estimate of the length of the primary infection period for apple scab (Gadoury *et al.*, 2004; Stensvand *et al.*, 2005). This will be used to determine when the last primary infection period occurs, and modified Mills criteria will determine when scab symptoms should be first visible, if any occur. At this point, trees will be scouted using a sequential sampling procedure similar to that used for the PAD analysis. If infections are present, they will be eradicated using appropriate fungicides. If the block is free of scab infections, fungicide sprays will be discontinued until the first applications targeting sooty blotch and flyspeck.

e. Sooty blotch and flyspeck — model-directed applications of reduced-risk fungicides and cultural management tactics. From petal fall, accumulated leaf wetting hours (ALWH) will be measured using standard hemp-string or electronic grid leaf wetness monitors in each orchard. At 270 ALWH, the first SBFS fungicide will be applied. This will consist of pyraclostrobin plus boscalid (Pristine; 16 oz./A) or captan plus calcium chloride (Captan 50 WP; 3 lb./A or equivalent plus 3.3 lb/100 gal of calcium chloride). Thereafter, fungicide protection will be reapplied following estimates of fungicide depletion. These are estimated to be after 2.5 inch of rainfall or three weeks, whichever occurs first, following Pristine; or after 14 days or 1.5 inches of rain for Captan+CaCl₂. These sprays will be continued until 30 days before predicted harvest. The ALWH will be measured from the estimated date of depletion of the final fungicide application. If ALWH reaches 250, a single application of Captan+ CaCl₂ using a low rate of captan (1.5 lb./A Captan 50WP or equivalent) will be used to prevent late or storage development of SBFS.

In blocks where the tree canopy is dense, growers will be advised to undertake a program of winter and summer pruning. In addition all blocks will be mowed to keep grass at 10 inch height or less.

f. Enhance fruit thinning without the use of carbaryl. In year 1, we propose to perform small-scale tests of naphthalene acetic acid (NAA Fruitone®) and 6-benzyladenine (BA, MaxCel®, Exilis®, RiteWay®) to further understand their use without carbaryl. We will use our standard approach of replicated trials, primarily at the UMass Cold Spring Orchard. Variables will include concentration ranges and cultivars. These data and those from previously conducted studies will help us formulate a set of new fruit thinning recommendations for NAA and BA. In year 2, block-sized trials at participating growers will be conducted with blossom thinners as an alternative to hormone- or carbaryl-based thinning. These trials will help growers better determine timing and concentration necessary to reduce crop load to acceptable levels by preventing pollination of an appropriate number of flowers.

2. Promote adoption of advanced apple IPM methods through grower demonstrations, educational meetings and publications, and a web site.

Faculty and staff at the University of Massachusetts and Cornell have significant Extension roles in apples, as well as their research programs. ARS scientists have collaborated with these scientists for several years, and have run applied research programs with growers in New England and New York. As a result, the coordination of research and Extension in the project will be seamless.

The unique aspect of this research is that it is taking methods that have shown promise as individual advanced IPM tactics and combining them in a single system. The use of grower blocks allows both the collection of research data and the demonstration of IPM tactics, both to cooperators and to growers attending on-farm meetings. This classic method has been used successfully in apple IPM for nearly 30 years in New England, and has led to nearly universal adoption of conventional IPM methods in the region.

Protocols for the advanced IPM system will be developed and printed, first for use by the cooperators and then for general use in Extension education. These will be available also on the program web site, which will be linked with NEWA and the UMass Fruit Advisor sites. Clements has extensive experience developing and maintaining Extension web sites, and he will coordinate the project site.

Collaborators also publish regularly in Extension journals, including the *New York Fruit Quarterly* and *Fruit Notes*. Results of each year will be published in these journals, and presented at grower meetings such as the New England Vegetable and Fruit Conference and the Empire State Fruit and Vegetable Expo.

The protocol of advanced IPM tactics for apples will be available to all growers via the web and at grower meeting presented in 2010. In addition twilight and similar on-farm meetings will be scheduled for collaborating orchards, to demonstrate methods. The presentation and publication program described above will be continued through to at least mid-2011.

Table 4. Timetable for project.

Objective	Coordination	Tasks	Time Frame
1. Development of advanced apple IPM system	D. Cooley	Select test and control blocks at each grower's orchard and mark	Feb-Mar '09
		Review advanced IPM tactics with growers and staff.	Mar '09; repeat Mar '10
		Distribute Trac-Apple Software, and train growers in its use as needed.	Feb-Mar '09
		Calculate baseline pesticide use and environmental impact data.	Mar-Dec '09
		Develop material for website and put on-line as ready.	Mar-Dec '09
a. Plum curculio.	T. Leskey and S. Wright	Deploy attractants in designated trap trees at bloom.	May-both yrs
		Weekly or bi-weekly sampling of trap trees.	May-Jun, both yrs
		Evaluate damage in advanced IPM and conventional plots.	Jul both yrs
b. Apple maggot.	T. Leskey and S. Wright	Deploy pesticide treated spheres in Advanced IPM plots.	Jul-both yrs
		Weekly or bi-weekly sampling of monitoring spheres.	Jul-Sep, both yrs
		Evaluate damage in advanced IPM and conventional plots.	Sep-both yrs.
c. OBLR, internal Lepidoptera.	H. Reissig	Select research blocks in cooperating NY growers farms	Mar-Apr 09
		Weekly sampling or monitoring of OBLR and internal Lepidoptera damage in research plots	Jun 15-Aug 30-both yrs
		Monitoring fruit damage from OBLR and internal Lepidoptera in research plots at harvest	Sep 14-Oct 15 both yrs
d. Eliminate OPs	H. Reissig	Develop a list of substitute insecticides for OP's, with list of properties relative to OP's.	Both yrs.

e. Apple scab	D. Cooley	PAD evaluation and calculated pray delay for next year.	Oct each yr (7 growers done'08)
		Obtain silver tip biofix for each block and monitor temperature, calculate degree days and determine end of primary scab season	Mar-Apr both yrs.
		Scout blocks for scab incidence following incubation period from final primary infection period; recommend fungicide delay.	May-Jun both yrs
f. Sooty blotch and flyspeck	D. Cooley	Evaluate block and surrounding area Mar and recommend pruning and border modification as needed.	Mar both yrs
		Determine petal fall date and monitor ALWH from then to 270; recommend fungicide.	May-Jul both yrs
		Monitor fungicide application dates and rainfall and notify growers of depletion.	Jun-Sep both yrs
		Monitor ALWH from 30 days before predicted harvest date; if 250 reached recommend low-rate captan+CaCl ₂	Aug-Sep both yrs
g. Thinning	W. Autio	Yr 1 trials at HRC in MA	Apr-Sep '09
		Implement non-carbaryl thinning recommendations in grower blocks	Apr – Jun '10
		Yr 2 trials of blossom thinning (oil, sulfur, ATS) in grower blocks	Apr-May, Sep '10
2. Promote adoption of advanced IPM	D. Cooley	Develop protocol document describing methods for use by cooperators; describe methods at general grower meetings	Mar-Jun '09
		Develop web site for communication between growers, researchers and staff; include connection to weather and protocol info.	Mar-Jul '09
		Present results of at grower meetings and IPM research/Extension meetings; publish results in Extension publications	Oct-Feb '09; repeat Oct-Feb '10
		Revise protocol and web site; make available to all growers	Oct-Feb '09
		Farm meetings at cooperating sites to demonstrate methods	Apr – Sep '10

(iv) Evaluation Plans.

Pesticide use records for this group of growers have been collected for two (6 growers) to five (5 growers) years in conjunction with another project. Pesticide records from other commercial apple growers in New England have been obtained from commercial consultants. This set of data will be used to calculate baseline pesticide use and impacts in terms of total pounds active ingredient used per season, a standardized measure of the number of applications (dosage equivalents = no. of applications made at the maximum label rate to the whole orchard or block), and the Environmental Impact Quotient as updated (Petzoldt, 2006; Kovach *et al.*, 1992).

During the study, these same calculations will be made for each year. In addition, we will record the amount of time needed to perform tasks that would be required of growers or consultants using the advanced system.

At the end of the study, use of the project web site will indicate interest in the advanced IPM methods. In addition, a brief survey will be given to growers via fruit newsletters (*Scaffolds* and *Healthy Fruit*) to gauge general grower interest in the methods.

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Project title: Development of Advanced Integrated Pest Management for Northeastern Apples

Project type: Joint Research-Extension

Project summary: A partnership among land-grant and USDA researchers, Extension and growers, has brought a unique skill set into development of an advanced integrated pest management (IPM) protocol for apples. The collaborators, including several growers, have worked on development of individual components of this system over recent years. The unique aspect of this project is it brings the most promising of these tactics together in a single management system. While the vast majority of apple growers in the Northeast use IPM tactics, progress in reducing toxic chemical inputs has stalled in recent years. The proposed system will introduce advanced IPM tactics that eliminate use of organophosphate pesticides, minimize the use of pesticides in general, and moves towards practical bio-intensive alternatives. The most important apple pests, including plum curculio, apple maggot, leafrollers and internal Lepidoptera, apple scab and the sooty blotch/flyspeck disease complex, will be addressed. The project also stretches beyond pest management per se to test alternative fruit thinning methods that will eliminate use of a carbamate pesticide. Because researchers in the project also have Extension appointments or significant experience with Extension, and have developed on-farm research and demonstration collaborations with growers, successful tactics will rapidly move into commercial use. Web-based communication will facilitate research and will provide

collaborating growers and eventually the industry in general with access to ways to implement advanced IPM. Traditional Extension methods, including widely read newsletters and journals, well-attended meetings, and on-farm demonstrations will insure broad industry awareness of the program.

Problem, Background and Description: Apple IPM has a long history in the Northeast, where apples are an important crop, valued at \$389 million in 2006. Over most of that history, IPM has decreased pesticide use in apples while maintaining or improving fruit quality and decreasing pest management costs. Over the past decade in spite of widespread IPM adoption by apple growers, pesticide use has remained steady or even increased. Resistance and cost issues have pushed growers to use increasing amounts of pesticides developed decades ago. While less expensive, these materials are generally more toxic to applicators, the environment and consumers. At the same time, consumers, retailers and processors increasingly recognize these problems, and demand fruit that has been grown using ecological production protocols that eliminate the most toxic pesticides, and substitute non-pesticide alternatives to all pesticides if possible. The market for conventionally-produced apples is slowly shrinking, and the regulations against some chemicals, such as the organophosphates, is growing.

Apple growers have recognized that new, bio-intensive IPM tactics are needed if they are to remain economically viable, and have identified specific needs in the Northeast IPM Center Tree Fruit Working Group Priorities, the National IPM Road Map, and the New England Apple Strategic Plan. Researchers have been addressing apple IPM issues identified by growers. This project proposes to combine several promising, advanced IPM tactics in a single advanced IPM program for Northeastern apples, and has the following objectives and anticipated outcomes.

Objectives and Anticipated Outcomes:

1. *Develop appropriate, advanced IPM tools for key apple pests in the Northeast that will reduce pesticide use and allow the use of less toxic materials where pesticides are necessary.*
 - a. *Plum curculio* - use a trap tree approach to replace general orchard sprays.
 - b. *Apple maggot* - use pesticide-treated sphere traps for management rather than general orchard sprays.
 - c. *Obliquebanded leafrollers and internal Lepidoptera* - use seasonal fruit monitoring programs for optimizing insecticide treatments.
 - d. *Eliminate OP's* and use pesticides with fewer non-target impacts.
 - e. *Apple scab* - use potential ascospore dose, inoculum destruction and degree-day model to delay initial fungicide applications in the following season and end applications when unnecessary.
 - f. *Sooty blotch and flyspeck* - develop model-directed applications of reduced-risk fungicides.
 - g. *Enhance fruit thinning without the use of carbaryl* - develop effective approaches that do not use carbaryl as a thinning agent.
2. *Promote adoption of advanced apple IPM methods through grower demonstrations, educational meetings and publications, and a web site.*

We anticipate that this project will reduce use of the most toxic pesticides in Northeastern orchards, reduce pesticide use overall, thereby opening markets and enhancing viability of the industry.

LOGIC MODEL FOR DEVELOPMENT AND DEMONSTRATION OF AN ADVANCED APPLE IPM SYSTEM

SITUATION: Annual pesticide use in apples is relatively high, and IPM-related annual decreases in the Northeast have stopped. Reliance on older pesticides faces regulatory and consumer problems. Market for apples produced "ecologically" is growing, while some markets will not accept use of some chemicals.

PRIORITIES: Develop and implement IPM programs and tactics that have major economic benefits and protect public health. More advanced monitoring and trapping methods for key arthropod pests, e.g. plum curculio, apple maggot and obliquebanded leafrollers;. Reduced fungicide use in apple scab and sooty blotch/flyspeck. Develop better "soft" pesticide programs that eliminate problematic pesticides, e.g. OPs, carbamates.

