



NIFA IPM Programs: Legacy and Impacts



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NIFA IPM Programs: Legacy and Impacts

In recent years Project Directors' Workshops have been instituted to provide a forum for grantees to share significant, positive impacts resulting from their projects funded by the National Institute of Food and Agriculture (NIFA). The requirement for a Project Directors' Workshop was initiated approximately three years ago but this 2012 Workshop will be the first such reporting opportunity for applied researchers and extension specialists in IPM-oriented programs including the Pest Management Alternatives Program (PMAP), the Crops at Risk Program (CAR), the Risk Avoidance and Mitigation Program (RAMP), and the Extension IPM Coordination and Support Program (EIPM-CS). Projects featured in the Workshop demonstrate the potential for implementation of project results, findings, and outcomes and include an economic analysis that addresses the feasibility of implementation. They also evaluate the feasibility for commercialization (including product registration, if necessary) of technologies developed as a result of the project. Projects selected for the Workshop demonstrate that objectives are responsive to pest management needs and priorities of stakeholders as identified through Pest Management Strategic Plans, Crop Profiles, documented Regional IPM Center priorities (www.ipmcenters.org/pmsp/index.cfm), Interregional Research Project #4 (IR-4) priorities (<http://ir4.rutgers.edu/>), and/or similar citable documents. Most importantly, projects funded through these grant programs are likely to result in outcomes that will provide a direct benefit to producers, leading to substantial near term impacts. A recent proposal to combine IPM grant programs at NIFA would aggregate the functions of these grant programs into a single IPM program to be called Crop Protection; however, the program is defined with a broader scope than exclusively crop pests.

Timeframe	Title	Presenter	Grant Program*	Page
6:30–6:40 pm	Opening Comments	Session Organizers: M. Johnson, National Program Leader, USDA/NIFA M. Draper, NPL/USDA/NIFA R. Nowierski, NPL/USDA/NIFA R. Meyer (retired), former NPL/USDA/NIFA		
6:40–7:00 pm	A Pest Management Program Using Reduced-Risk Pesticides, Eco-Apple Protocols, and Value-Added Marketing for NY and New England Growers	D. R. Cooley University of Massachusetts-Amherst Moderator: M. Draper	CAR	4
7:00–7:20 pm	Biologically Based Integrated Management of Bacterial Leaf Diseases on Leafy Brassica Greens	A. P. Keinath Clemson University Moderator: M. P. Johnson	PMAP	7
7:20–7:40 pm	Integrating Mating Disruption, Pest Phenology, and Selective Insecticides for Sustainable Grape Berry Moth Management	R. Isaacs, L. Teixeira & K. Mason Michigan State University Moderator: M. P. Johnson	PMAP	9
7:40–8:00 pm	Break			
8:00–8:20 pm	Reduced-Risk IPM Strategies for Sustainable Livestock Production	C. Schal North Carolina State University Moderator: R. Nowierski	RAMP	13
8:20–8:40 pm	Outcomes and Successes From an Established Extension IPM Program	D. Polk & G. Hamilton Rutgers University Moderator: M. Draper	EIPM-CS	16
8:40–9:00 pm	A Case Study of Infrastructure & Leverage as Critical Elements of Outcome-Driven Research and Outreach	P. Ellsworth & A. Fournier University of Arizona Moderator: R. Nowierski	EIPM-CS	19
9:00–9:30 pm	Panel Discussion–Q&A			

*Funding for the projects was partially or totally provided by the grant programs.

Integrated Pest Management

Regionally Focused Programs

Regional Integrated Pest Management Centers function as a national pest management information network designed to respond quickly to information needs in both the public and private sectors. The Centers help NIFA and its partner institutions identify, prioritize, and coordinate national pest management research, education, and extension programs. The IPM Centers are the focal point for team-building efforts, communication networks, and stakeholder participation.

www.nifa.usda.gov/nea/pest/in_focus/ipm_if_regional.html

Regional Integrated Pest Management Program (RIPM) is managed regionally by the Regional IPM Centers and supports the development and implementation of new and modified IPM tactics and systems, their validation in production systems, and the delivery of educational programs to pest managers, advisors, and producers. The program builds stakeholder partnerships to address critical pest management needs in each region.

www.nifa.usda.gov/fo/funding.cfm

Pest Management Alternatives Program (PMAP) supports the development and implementation of pest management alternatives when regulatory action, voluntary action by the registrant, or other circumstances results in the unavailability of certain pesticides or pesticide uses. Through these grants, new pest management tools and techniques are developed to address critical pest problems identified by pest managers and other stakeholders. This program works with the Regional IPM Centers to identify and address regional priorities established by stakeholders.

www.nifa.usda.gov/fo/pestmanagementalternatives.cfm

Nationally Focused Programs (discovery to implementation)

Base Support to Land-Grant Universities (LGUs). The underpinning of the national extramural agricultural research, education, and outreach capability is accomplished through a federal-state partnership with the LGU system. NIFA provides oversight for the federal annual base support that is provided through Hatch, Smith-Lever, McIntire-Stennis, Evans-Allen, and 1890 Extension Acts. The federal funds are matched and multiplied by state and local resources in support of the national agricultural research, education, and extension infrastructure.

Risk Avoidance and Mitigation Program (RAMP)—discontinued in 2011—supported the development and implementation of innovative IPM systems on an area-wide or landscape scale. It was designed to maintain crop productivity and profitability and, at the same time, address environmental quality and human health issues. The program provided support for major acreage crops, as well as key fruit and vegetable production systems, and other agroecosystems. Projects funded by this program were medium-term, involving systems approaches targeted at eliminating or minimizing pesticide residues in key foods, soil, and surface/ground water. Funded projects tended to be multi-state or regional in scale, and typically involve multiple pest species in multiple cropping systems with emphasis on enhanced stability and sustainability of IPM systems.

www.nifa.usda.gov/fo/riskavoidancemitigationicgp.cfm

NIFA Homepage:
www.nifa.usda.gov

Pest Management Information:
www.nifa.usda.gov/nea/pest/pest.cfm

The mission of NIFA is to advance knowledge for agriculture, the environment, human health and well-being, and communities.

Specialty Crop Research Initiative (SCRI) supports research and extensions efforts to identify and address threats from pests and diseases, including threats to specialty crop pollinators. In addition, plant breeding, genetics, and genomics research is supported to improve crop characteristics, such as pest and disease resistance resulting in reduced application management strategies.

www.nifa.usda.gov/fo/specialtycropresearchinitiative.cfm

Integrated Organic Programs supports the development and implementation of biologically-based pest management practices that mitigate the ecological, agronomic, and economic risks associated with a transition from conventional to organic agricultural production systems based on national standards. These programs include funding from the Organic Agriculture Research and Extension Program (OREI) and the Organic Transitions Program (ORG). www.nifa.usda.gov/organicagriculture.cfm

Crops at Risk (CAR)—discontinued in 2011—addressed short-term, applied research, education, and extension in IPM for crop and cropping systems. The goal of this program was to develop or modify multiple-tactic IPM systems and strategies focused on specific crop production systems.

www.nifa.usda.gov/fo/cropsatriskicgp.cfm

Methyl Bromide Transitions (MBT) supports the discovery and implementation of practical pest management alternatives to methyl bromide, or reduction of methyl bromide emissions, for uses which the United States is requesting critical use exemptions. www.nifa.usda.gov/fo/methylbromideicp.cfm

Critical Issues: Emerging and New Plant and Animal Pests and Diseases—discontinued in 2011—was designed to provide one-time seed funding to help initiate work requiring immediate attention until other longer-term resources could be secured to address the issue. NIFA solicited proposals annually to address specifically identified new or emerging issues.

www.nifa.usda.gov/fo/criticalissuesplantandanimalpestsanddiseases.cfm

Minor Crop Pest Management (IR-4) is the principal public program supporting the registration of pesticides and biological control agents for use on specialty crops. The program provides coordination, funding, and scientific guidance for both field and laboratory research to develop data in support of registration packages to be submitted to EPA. IR-4 coordinates the cooperation of commodity producers, state and federal research scientists, and extension specialists in identifying and prioritizing pest control needs. The program is jointly funded by NIFA and the Agricultural Research Service.

www.nifa.usda.gov/nea/pest/in_focus/pesticides_if_minor.html

Extension IPM Coordination and Support Program (EIPM-CS) supports regional, state, institutional, and local efforts in advancing the goals of the National Roadmap for Integrated Pest Management by addressing priority needs associated with the coordination, design, development, implementation, and evaluation of Extension IPM programs. EIPM-CS funds help agricultural producers and other pest managers adopt alternative pest management practices through training, demonstration, and evaluation of methods and strategies.

www.nifa.usda.gov/fo/extensionipmcoordinationandsupportprogram.cfm

Pesticide Safety Education Program (PSEP) provides educational programs that support the proper use of pest management technologies. A central focus is to provide pesticide applicators with the knowledge and training needed to safely and effectively use pesticides. Education is provided by LGU extension programs in conjunction with state regulatory agencies that certify and license applicators. NIFA manages the program through funds allocated by EPA.

www.nifa.usda.gov/nea/pest/in_focus/pesticides_if_psep.html



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A Pest Management Program Using Reduced-Risk Pesticides, Eco-Apple Protocols, and Value-Added Marketing for New York and New England Growers

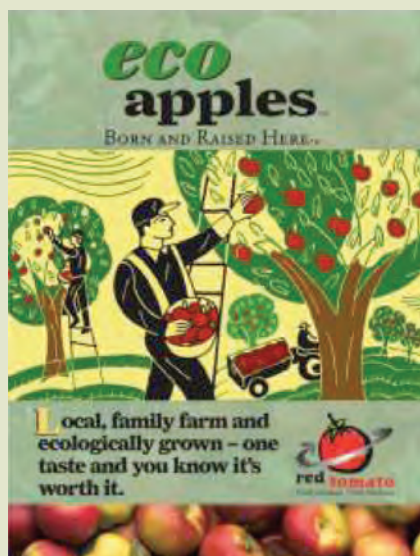
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The basic concept behind the Eco Apple Program is that more advanced IPM practices are generally more expensive to implement than conventional pest management, and if growers are to use them they must receive some benefits, particularly increased revenue. Growers participating in the Eco Apple project agreed to adhere to a production protocol that stressed minimal pesticide use, and low-risk pesticides when necessary, and in return worked with the non-profit wholesaler Red Tomato, Inc. in an eco-label program that also stressed a connection with the individual growers. (<http://redtomato.org/ecoapple.php>) The project team consisted of research and extension scientists at the University of Massachusetts and Cornell University, Red Tomato, Inc., the IPM Institute of North America, two independent IPM crop consultants, and 11 apple growers in New England and New York.

The Eco Apple Protocol developed by the IPM Institute of North America (web-published at www.ipminstitute.org) included minimum requirements (legal, worker protection standard-related, soil and water conservation, pesticide use and hazard reduction, pest-specific practices, grower education and self-improvement, food safety and product quality) and advanced practices (many of the same categories). Growers chose which advanced practices to apply, but had to have 20 of them each year. Pesticides were ranked according to hazard (process led by IPM Institute): materials to be used with justification (green), materials to be used with restrictions (yellow), and materials that could not be used (red). These rankings were carefully examined each year. The organo-phosphate insecticides, for example, were placed on the “do not use” list during the course of the project.

Grower adherence to the Protocol was verified by an on-site, independent third-party inspection prior to harvest. Each year advanced IPM strategies for major apple pests were updated, reduced-risk pesticide programs were re-designed, the Eco Apple Protocol/ Grower Self-Assessment was improved and updated, and a Quick Guide for Growers was produced. Participating growers completed an extensive self-assessment, paid an annual certification fee, submitted scouting records, and participated in university-led advanced IPM research and demonstration projects in their orchards. Growers were provided with software for tracking pesticide use (TracApple), and trained to use the program. Pesticide records (and records of fertilizer, thinners, and growth regulator applications) were submitted and analyzed.



At harvest, the crop was evaluated by university scientists for damage caused by pests (approx. 1000 apples per 5 acre block). Pest control in Eco Apple blocks of apple trees was generally as effective as that in growers' previous years. Many of the orchards put their entire acreage into the program, so an on-site comparison with a grower "standard" or "conventional" block was not possible. Pest damage was kept below economic-injury levels.

During the project, advanced IPM strategies were developed and improved for key apple pests. For all pests, reduced-risk pesticides were evaluated and recommended.

- **Scab:** Resistance of apple scab disease to 3 classes of fungicides was determined at most orchard sites. Fungicide applications were reduced for scab by delaying the first fungicide spray each year at most sites. Scab inoculum levels were measured in the fall, and sanitation measures used to reduce overwintering scab inoculum. Degree day models and modified Mills periods were also used to time sprays.
- **Sooty blotch/flyspeck:** Reliance on calendar-based sprays was replaced with timing summer disease sprays according to model predictions that used weather data based on accumulated leaf wetness to predict the development of the disease. Orchard blocks were divided into disease risk levels, based on examination of disease inoculum in bordering woodland habitat. Low risk blocks were sprayed less. Rainfall data that predicted wash-off of sprays was also used.
- **Fire blight:** Previous history, canker removal, and early copper applications were used for fire blight management. These were followed by use of weather data to run the Cougar Blight model to predict risk and optimize streptomycin applications.
- **Plum curculio:** After a petal fall spray, only "perimeter" sprays or "frame" sprays were used to manage the pest. Sprays were terminated according to an oviposition model.
- **Leafrollers:** Larval sampling and adult feeding damage assessments were used in conjunction with judicious use of insecticides.
- **Codling moth, oriental fruit moth, and lesser apple worm:** Previous history, risk classification systems, pheromone trap catch thresholds, and repeated fruit sampling plans were employed to manage these pests. High-risk blocks also received mating disruption. Provisional thresholds were refined.

Each spring a two-day meeting brought all team members together to evaluate the successes and failures of the previous season and to begin the plan for the new season. Monthly conference calls and smaller group meetings kept the team on track. The project divided into two major objectives: producing the crop according to advances in IPM and marketing the crop so that the grower and the consumer could benefit from these advances.

Marketing the crop: During 2007, the first growing season of the project, the Eco Apple project grew from 6 to 12 growers, and from \$400,000 for 18,000 cases of apples to about \$1.4 million for 60,000 cases. There was an increase in certified acres from 475 in 2006 to 771 in 2007. In addition to the essential brokerage efforts of Red Tomato, their marketing experts reworked the packaging, revised the text and created new versions of the "tote", with individual info for each orchard. They also created new FAQ info and developed new point-of-sale materials, including signs and banners. The new slogan was: "Trust the Farmer, Know the Orchard, Love the Fruit". In 2008, they developed case labels, refined the Eco Apple tote box, and designed and launched the Eco Apple PLU stickers. Red Tomato deepened relationships with 3 truckers to distribute less than full loads and added 2 new growers to the group. They contributed to outreach efforts of the project with website and video production, numerous workshops at orchards and





produce vendors (e.g., Whole Foods), and worked to position Advanced IPM as part of the Eco Apple and Red Tomato brand. In 2009, three new growers were added.

Outcomes/Impacts: The project improved the market share of IPM-grown apples, improved profitability for growers using the Eco Apple system, and directly increased the adoption of sustainable pest management strategies in approximately 1,000 acres in the Northeast. Many more acres saw increased adoption due to grower education and outreach by members of the project team. Numbers of Eco Apple growers continue to increase with 22 signed-up for the 2012 season. Numbers of cases and total dollar amounts have fluctuated with price deflation and volume constraints caused by hail and frost damage each season, but have remained stable over the several years. The Eco Apple Protocol has been adapted for use in Pennsylvania, Wisconsin, and Minnesota, where it impacts new groups of apple growers. Programs for peaches and tomatoes are in development. The impacts of Eco Apple promotional and consumer education materials are hard to measure but real. In addition to the 20 apple growers participating, approximately 150 growers received training and exposure to project ideas and actions at grower meetings and workshops throughout the Northeast and Wisconsin. Changes in knowledge about pest management were significant. Changes in actions included improvements in documentation of pesticide applications and a shift towards more pest monitoring, more carefully timed sprays, use of predictive pest models, and use of greener and more specific materials.

Biologically-Based Integrated Management of Bacterial Leaf Diseases on Leafy Brassica Greens

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Since 2001 and up to the present, two bacterial leaf diseases have threatened turnip and mustard greens in South Carolina. Yearly losses have been as much as \$1.7 million. Bacterial blight caused by *Pseudomonas cannabina* pathovar *alisalensis* and a *Xanthomonas* leaf blight caused by a unique strain of *Xanthomonas campestris* pathovar *campestris* form a bacterial disease complex on leafy brassica greens (Fig. 1). *Pseudomonas* is present in the spring and late in the fall, while *Xanthomonas* predominates in the hot summer months. In this project, fertility, bactericides, and host-plant resistance were tested to manage bacterial blights on turnip and mustard greens in field experiments on farms and at the research center.

In three experiments on commercial farms, two levels of nitrogen and potassium fertility were examined with and without magnesium sulfate in a split-plot design with six treatments. High nitrogen enhanced symptoms of both *Pseudomonas* and *Xanthomonas* leaf blight. Although it increased total weight of harvested leaves, it also increased the weight of diseased leaves. Potassium and magnesium sulfate had no effect on disease, yield, or quality (color) of turnip greens. Severity of *Pseudomonas* blight was 33% in the very susceptible turnip green *Brassica rapa* 'Topper' and 2.4% in the moderately susceptible cultivar 'Alamo.' 'Topper' was the preferred cultivar prior to 2002; since then, growers have switched to 'Alamo.'

In two experiments, application of the systemic-acquired resistance inducer acibenzolar-S-methyl (Actigard) reduced *Pseudomonas* blight on the susceptible mustard green *B. juncea* 'Florida Broadleaf'. Actigard had no effect on disease severity on the resistant mustard green Plant Introduction G30988, as the level of resistance was higher than the level of control provided by Actigard. Actigard increased weight of healthy leaves in the spring but not in the fall. It reduced weight of diseased leaves in both experiments. Copper hydroxide was phytotoxic to mustard greens. However, copper hydroxide, copper salts of fatty and rosin acids, and mefenoxam plus copper hydroxide were not phytotoxic to turnip greens.

Resistance identified in the greenhouse to *Pseudomonas* leaf blight was confirmed in Plant Introduction lines *B. rapa* G30499 and *B. juncea* G30988 in the field in three experiments in spring and fall. Both resistant lines had less disease and higher yields of marketable leaves than susceptible commercial cultivars of the same crops (Fig. 2). Kale *B. oleracea* 'Blue Knight' also was resistant. However, the market for kale is not as large as it is for turnip and mustard greens.

In the fall 2011 experiment in Charleston, 12 cultivars or PI lines were inoculated with *P. cannabina* pathovar *alisalensis*.



Figure 1. Yield loss in turnip greens due to *Xanthomonas* leaf blight.



Figure 2. Fall 2011 field experiment on bacterial blight (*Pseudomonas*).

Top row: resistant mustard green *B. juncea* G30988

Second row from top: resistant turnip green *B. rapa* G30499

Second row from bottom: highly susceptible "spinach mustard" *B. rapa* 'Tendergreen'

Bottom row: susceptible mustard green 'Florida Broadleaf'

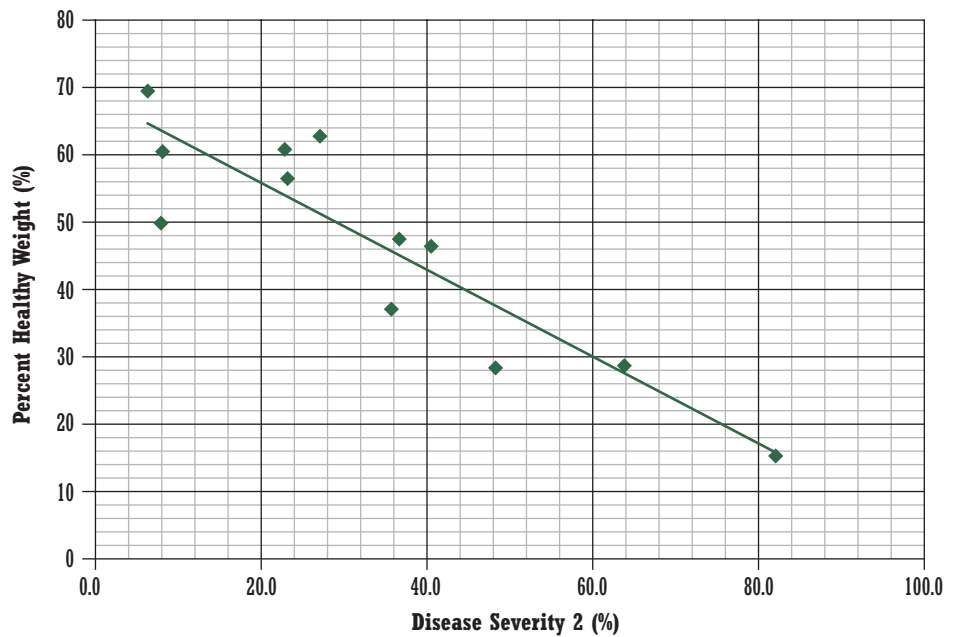


Figure 3. Correlation between disease severity and percentage healthy weight in 2010. Data points are means for 12 cultivars and lines.

Across all 12 cultivars and lines, there was a highly significant correlation ($r = -0.896$, $P = 0.0001$) between visual ratings of percentage diseased leaf area (severity) with percentage of healthy leaves harvested (by weight) (Fig.3). This lends confidence to our evaluations of the effects of treatments by rating disease symptoms. Incremental reductions in diseased leaf area also should increase marketable yields.

The resistance to *Pseudomonas* in Plant Introduction G30988 is likely controlled by two recessive genes. Progeny of crosses of G30988 by two susceptible parents were intermediate in resistance, i.e. not as resistant as the resistant parent but noticeably less susceptible than the susceptible parent. Resistant mustard green *B. juncea* G30988 has been evaluated by cooperating growers who grow several thousand acres of mustard greens. It has acceptable commercial quality. Discussions are underway with a seed company about the possibility of increasing seed for large-scale field trials.

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Integrating Pest Phenology, Selective Insecticides, and Mating Disruption for Sustainable Grape Berry Moth Management

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Grape berry moth (GBM) is the most damaging insect pest of Michigan's 13,000 acres of juice grape vineyards. In sites with high populations, 75–100% of grape clusters on vineyard borders adjacent to woodlots can be infested with GBM, leading to economic loss and increased disease pressure (Figure 1). This project developed and enhanced promising IPM program components for this pest, by improving knowledge of pest biology, optimizing use of selective insecticides, and enhancing opportunities for growers to increase adoption of non-chemical techniques.

Degree day model

An online pest phenology model based on published developmental parameters was created and promoted by Michigan State University to aid growers in determining when to apply insecticides. This relates GBM development to the phenology of wild grape (*Vitis riparia*), predicting the start of second and third generation egg laying. The GBM model is available at www.enviroweather.msu.edu. This model is used to time application of long lasting insecticides that are active on eggs and young larvae (e.g. Intrepid, Altacor). Most conventional (broad-spectrum) insecticides have shorter periods of activity so it is recommended to wait until egg hatch is underway ~100 Growing Degree Days after the start of egg laying for these compounds.

Improved control with well-timed selective insecticides

An additional challenge for GBM control is the higher cost of new insecticides compared to conventional insecticides. Growers may be able to compensate for the higher cost by using them only on the borders when and where there is high pressure from GBM. We compared the efficacy of standard and IPM-based grape insect control programs, by measuring the effectiveness of grape berry moth (GBM) controls applied in small plot and on-farm trials at timings based on the MSU GBM model. In on-farm trials we also used this model to test if border sprays of reduced risk insecticides give comparable and economical control of GBM to conventional insecticides applied to the entire vineyard.

Small plot trial. A replicated trial was established in a Michigan vineyard (c.v. Concord) to test whether insecticide applications based on timings from the MSU GBM degree day model provide improved GBM control compared to that in grower standard programs. Twenty individual plots, each containing five vines, were assigned to five treatment groups in a randomized block design with four replicates. The experimental plots received no insecticides except those used in this study. Four GBM damage assessments were done (7 Jul, 28 Jul, 3 Sep, 1 Oct, 2009) by examining 50 clusters in each plot and recording the number of damaged clusters and the severity of damage in those clusters (total number of damaged berries). GBM damage was compared



Figure 1. Grape cluster infested by grape berry moth.

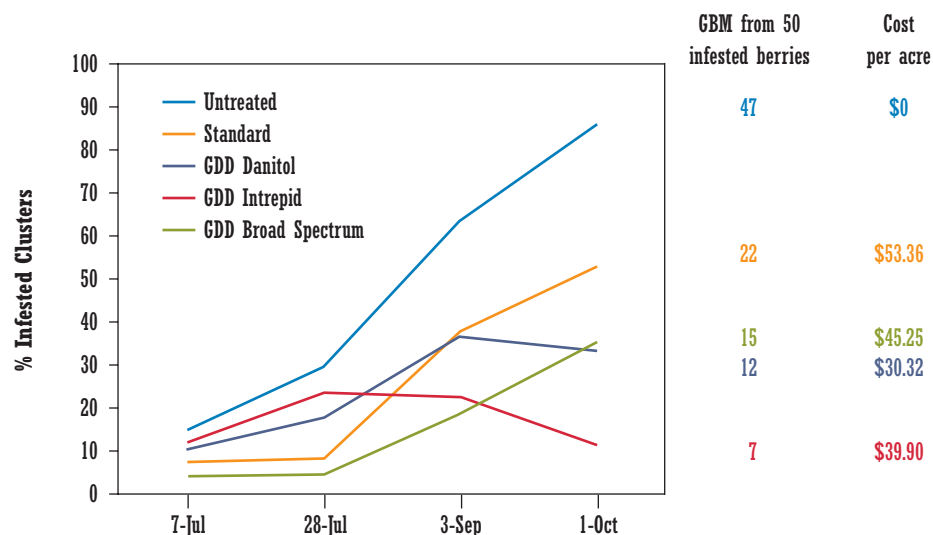


Figure 2. GBM damage on vines receiving different insecticide programs. Standard program is based on standard recommendations. The GDD Broad Spectrum program incorporates degree day timings into a spray program typical for Michigan juice grape growers.

among treatments using ANOVA. At the preharvest assessment (1 October), damage in the GDD Intrepid treated plots was significantly lower than in all other treatments (Figure 2). This illustrates the longer residual activity of Intrepid compared to the broad spectrum insecticides used in the other treatments (Danitol, Sevin and Imidan). Another important point to make is that the GDD Intrepid (and GDD Danitol) programs did not use a post bloom insecticide, yet these programs resulted in control that was comparable or better than programs that used three insecticide applications. The lower damage in the GDD Intrepid plots also represents a substantial benefit for the grower in reduced yield loss, less risk of insect contamination and less risk of harvested fruit being rejected by a fruit processor.

On farm trials. Four vineyards (c.v. Concord or Niagara) with a history of GBM infestation were chosen at each of five commercial grape farms in southwest Michigan. At each farm, a vineyard received one of the treatment programs (see descriptions in Figure 3), including Specialized Pheromone and Lure Application Technology (SPLAT) treatments for mating disruption. The 10 rows of vineyard bordering adjacent woods (comprising approximately 1 acre) was considered the border and the remainder of the vineyard was considered the interior. This distinction was used to allow specific treatments and sampling in areas with high GBM pressure (border) separate from low pressure areas (interior). At each farm the grower applied the insecticide treatments, and the same standard fungicide program was applied to all vineyards. Records of insecticide applications are available from the authors.

Three GBM damage assessments were performed to compare programs: postbloom (22 Jun to 2 Jul); veraison (16 Aug); and pre-harvest (29 Aug to 9 Sep) by examining 100 clusters on the border and 100 clusters on the interior of each vineyard. Immediately pre-harvest, fifty infested grapes were collected from the borders of each vineyard (23 Aug to 9 Sep). Grapes were placed in deli containers and held for 6 weeks to allow development of insects in the grapes. At that time, GBM survival was determined and compared among treatments. Yellow sticky traps were deployed in all vineyards every two weeks during the season to measure natural enemy response to the different programs. Major groups of natural enemies were identified and counted totals were compared between programs.

In all vineyards GBM damage was higher at vineyard borders compared to vineyard interiors (Figure 3). There were significantly fewer damaged berries at the borders of

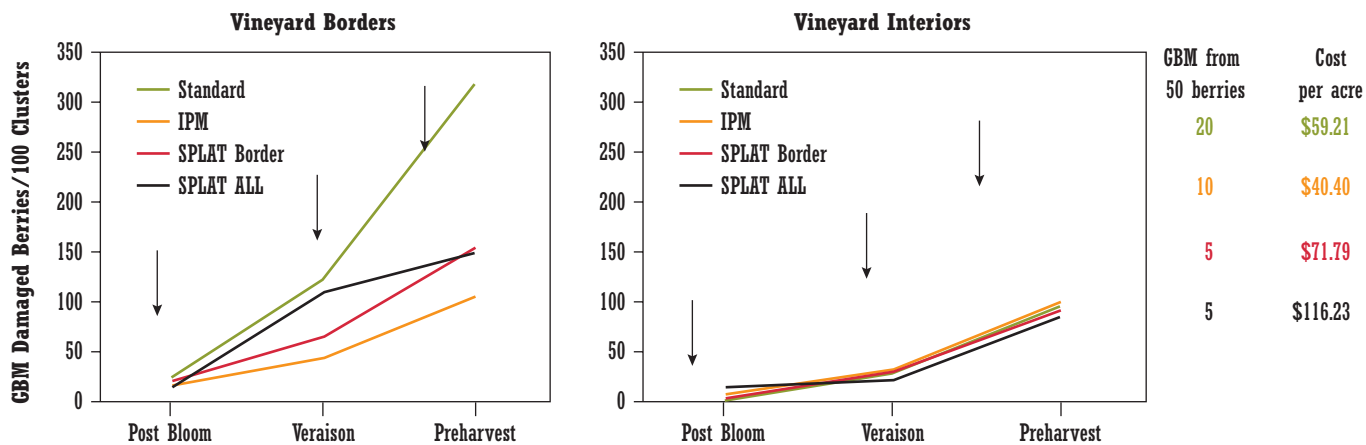


Figure 3. GBM damage in border (left) and interior (right) samples from four GBM management programs through the 2010 growing season. Arrows indicate timing of insecticide and SPLAT-GBM applications. The standard program was broad spectrum insecticides applied to the entire vineyard, and the IPM program was border sprays of reduced-risk insecticides. SPLAT Border signifies GBM-SPLAT applied to the 10 rows adjacent to woods, SPLAT All indicates application to the entire vineyard. GBM survival and per acre cost of each program are shown in the columns on the right.

vineyards treated with the IPM program at the veraison assessment compared with that in the Standard or SPLAT all treatments ($P=0.008$; Figure 3, left). GBM damage at border locations was also higher in vineyards treated with the standard program compared to that in all other treatments at the preharvest assessment ($P=0.004$; Figure 3, left).

The reduction in GBM damage at border locations in the SPLAT treated vineyards is likely due to insecticides that growers needed to apply in addition to SPLAT treatments. There were no differences in damage among programs in vineyard interiors at any sampling time (Figure 3, right). It is important to note that GBM damage in vineyard interiors was similar in vineyards that received insecticides (Standard and SPLAT border) and in vineyards that were not treated with insecticides (IPM).

There were no significant differences in GBM survival among treatments, however more GBM survived in vineyards treated with the Standard program compared to all others (Figure 3). No differences were detected between programs for any of the natural enemies caught on yellow sticky traps.

Vineyard SPLAT applicator—The SPLAToGator

To address the need for a rapid and cost-effective applicator for SPLAT-GBM, we designed and built an applicator, called the SPLAToGator (Fig. 4). It combines compressed air routed to a 3 gallon canister containing SPLAT, a T-junction and hoses running to two solenoids supported on a metal frame, and an electronic timer that can be set for the appropriate frequency and duration for opening the solenoid. For a set tank pressure and ground speed, the SPLAToGator delivers a precise number of uniformly sized drops per vine.

We simplified loading the canister by adding quick coupler connections to the outflow so the tank could be removed for easy filling. We replaced the liquid nitrogen pressurization system with a 7 gallon refillable air tank and a 12volt air compressor wired into the Gator's electrical system, and we added extensions to the solenoid valve nozzles to reduce shearing of SPLAT droplets as they are deposited in the canopy.



Fig. 4. Gator-mounted mechanical applicator for treatment of vineyards with SPLAT-GBM. Width of the applicator boom can be adjusted for different trellis systems and row spacing (top). Close-up of refillable air tank and SPLAT canister (bottom).



One person can apply SPLAT to 10 acres of vineyard per hour, a tenfold improvement over manual application. In the course of this project we made several improvements to the SPLAToGator to make this machine a viable applicator for commercial use.

Summary

Using the new GBM degree day model to time border-targeted applications of new insecticides provides effective control of GBM. At all five farms in our study, the per acre cost for insecticide was lower for vineyards treated with the IPM Program compared to the Standard Program. Focusing control efforts on high pressure areas, i.e., vineyard borders, is an effective way to manage GBM, both in terms of reducing damage and reducing insecticide costs. This approach has been adopted widely in Michigan due to the strong economic benefits for growers. SPLAT-GBM provided reduction of infestation at vineyard borders but is currently not a cost-effective means of controlling this pest in conventional vineyards.

This project supported the further development of IPM programs for eastern US vineyards, and the results have been shared with researchers, extension colleagues, growers, and consultants. Adoption of the degree day model and selective insecticides has increased because of this project, reducing the environmental footprint of Michigan viticulture, and contributing to the sustainability goals of National Grape Cooperative, Welchs, and the Michigan Grape and Wine Industry Council.

We thank the cooperating grape growers and the United States Department of Agriculture Pest Management Alternatives Program for support of this project.

Reduced-Risk IPM Strategies for Livestock Production

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Cockroaches have long been recognized as important pests in human-inhabited structures, and infestations are associated with disease transmission and allergen dissemination. Pork production is an important agricultural component of several states' economies. The U.S. inventory of all hogs and pigs on December 1, 2011, was 66 million head (<http://usda.mannlib.cornell.edu/>). The total number of hog operations in the U.S. was 75,350, and although farms with >2,000 hogs accounted for only 18% of the farms, they also accounted for 75% of the swine inventory in 2004. Sampson and Duplin Counties, where much of our research is conducted, are the largest swine-producing counties in the U.S. The favorable indoor habitat of confined swine operations and an abundance of food and water can sustain large populations of pest cockroaches (Fig. 1).

Our goal is to engage in long-term efforts to develop reduced risk IPM strategies for swine production on a regional scale. Our *Specific Objectives* are to:

1. Validate visual and pheromone-based sampling techniques for cockroaches relative to worker concerns and herd health.
2. Develop and evaluate reduced-risk, ecologically based, integrated pest management information-intensive approaches for pest suppression.
3. Demonstrate the efficacy of this program and quantify reduction in risks to animal and human health, and the environment.

Impact of the German cockroach on workers and swine

The German cockroach, *Blattella germanica* (L.), has been implicated as a major cause of allergic disease. Although there appears to be a positive correlation between exposure to German cockroach infestations and respiratory disease in residential settings, little is known about exposure in the workplace. The confined swine production environment often supports large cockroach infestations, which can be expected to expose workers and animals to high levels of allergens. We examined the production and distribution of one of several allergens present in the German cockroach—Bla g1—that can trigger asthma. Our biological studies, summarized in Gore and Schal (2007)¹, show that Bla g1 is produced in large amounts in the midgut of feeding cockroaches. The spatial distribution of Bla g1 on a swine farm was also examined in relation to cockroach population level and production practices. Settled dust on floors and other surfaces in various rooms were sampled with a modified vacuum cleaner. High levels of Bla g1 were found on all surfaces, suggesting extensive worker and animal exposure to this allergen. Insight into the environmental distribution of Bla g1 should aid in understanding its interaction with other farm allergens and in developing allergen mitigation plans.

¹ Gore J. C. and C. Schal. 2007. Cockroach allergen biology and mitigation in the indoor environment. *Annual Reviews of Entomology* 52: 439–463 (<http://www4.ncsu.edu/~coby/schal/2007Gore&SchalARE&SM.pdf>).



Figure 1. Distribution of hog farms throughout Eastern North Carolina, primarily in Duplin and Sampson counties (top). Infestations of German cockroaches, *Blattella germanica* (bottom) in commercial swine farms. On the right is a typical 1/4 of a farrowing room.

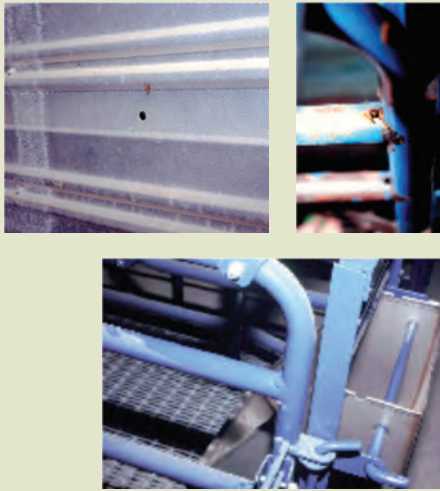


Figure 2. Physical aspects. Top left: Delivery holes in walls permitting delivery of boric acid, fungi, and residual insecticides. Effect of sealing farrowing crates on cockroaches within crates. The crate on the top right shows cockroaches. The crate on the bottom was manufactured, upon our recommendations, to eliminate refugia for cockroaches.

Of equal concern for workers and animals is the German cockroach's ability to acquire and transfer pathogens, and its potential as an agent of transmission for antibiotic resistant microbes in livestock production systems in piglet feces. We screened the gastrointestinal microbial community of German cockroaches from several farms in eastern North Carolina for verotoxigenic *Escherichia coli* F18. Viable and virulent cells of *E. coli* F18 were detected in cockroach feces for up to 8 days after initial exposure in densities comparable to those found in piglet², showing that cockroaches may serve as important mechanical vectors of pathogenic *E. coli*. We also isolated, quantified, identified, and screened for antibiotic resistance and virulence of enterococci from the digestive tract of house flies, German cockroaches and pigs. We found that the majority of samples were positive for enterococci, and multi-drug resistant enterococci were common from all three sources. Moreover, cockroaches and house flies shared some of the same enterococcal clones that we detected in swine manure, indicating that insects acquired enterococci from swine manure³. Coupled with our studies on the population genetics of cockroach in the swine environment⁴, these findings show that house flies and German cockroaches in the confined swine production environment likely serve as vectors and/or reservoirs of antibiotic resistant and potentially virulent enterococci and consequently may play an important role in animal and public health.

Reduced-risk approaches

In addition to developing action thresholds based on visual counts, we evaluated the following options for solutions to the pest management problem:

- 1. Physical control:** Hog barns are not well constructed, offering ample refugia for pests. We developed a strategy to reduce pest populations by removing such harborages and shelters. Unlike residential situations, caulking and sealing is impractical and uneconomical in this environment. This has been accomplished through selective use of long-acting inorganic insecticides, namely boric acid, delivered through access ports in the walls (Fig. 2). Moreover, the hollow metal bars comprising the hog crates offer refugia for cockroaches that subsequently gain ready access to feed, water and nursing pigs. Sealing some of these access holes has allowed us to target the remaining holes with low-impact bait insecticides. Manufacturers of commercial crates have recently adopted our recommendations to produce solid and seamless crates (Fig. 2).
- 2. Cultural practices:** A component of bio-security is the periodic power washing and disinfection of rooms. While this practice presumably reduces disease transmission, it also removes residual insecticides. An option that we adopted in our current work is to reduce by 50% the frequency of washing the walls. Since cockroaches, spiders, and flies are most abundant on/in walls, this has significantly reduced insecticide use while increasing the efficacy of our pest management program.
- 3. Biological control:** The swine production environment offers a unique opportunity to re-visit and evaluate the efficacy of biological agents in a high humidity, moderate temperature habitat. We showed that boric acid synergizes the activity of *M.*

² Zurek, L. and C. Schal. 2004. Evaluation of the German cockroach, *Blattella germanica*, as a vector of verotoxigenic *Escherichia coli* F18 in confined swine production. *Veterinary Microbiology* 101: 263–267 (<http://www4.ncsu.edu/~coby/schal/2004ZurekVetMicrov101.pdf>).

³ Ahmad A., A. Ghosh, C. Schal and L. Zurek. 2011. Insects in confined swine operations carry a large antibiotic resistant and potentially virulent enterococcal community. *BMC Microbiology* 11: 23 (<http://www.biomedcentral.com/1471-2180/11/23>).

⁴ Booth W., R. G. Santangelo, E. L. Vargo, D. V. Mukha and C. Schal. 2011. Population genetic structure in German cockroaches (*Blattella germanica*): Differentiated islands in an agricultural landscape. *Journal of Heredity* 102: 175–183 (http://www4.ncsu.edu/~coby/schal/2011BoothJ_Heredity_Swine.pdf).



*anisopliae*⁵. A new densovirus⁶ appears to be a promising new agent in biocontrol, but work is in progress to evaluate its efficacy.

4. Pesticides: Pyrethroids have been highly effective, but because of pyrethroid resistance, a key feature of our work is to minimize the use of pyrethroids to manage resistance to this class of insecticides. We have documented that granular baits are highly effective. Also, boric acid offers an excellent margin of safety, no insecticide resistance, low cost, and good efficacy. We have found boric acid to be highly effective in both dust⁷ and liquid bait formulations⁸ (Fig. 3). Likewise, the Insect Growth Regulators hydroprene and pyriproxyfen were extremely effective.

Overall, this program resulted in (a) greater appreciation of the importance of insect pests in the swine production system, (b) significant reductions in insecticide use, (c) delaying the evolution of pyrethroid resistance, (d) adoption of reduced-risk pest control approaches, and (e) better educated practitioners.

Supported in part by the Risk Avoidance and Mitigation Program (2005-51101-02388) and the Agriculture and Food Research Initiative Competitive Grants Program (2009-35302-05303) of the USDA National Institute of Food and Agriculture, and the Blanton J. Whitmire endowment at North Carolina State University.

⁵ Zurek L., D. W. Watson, and C. Schal. 2002. Synergism between *Metarhizium anisopliae* (Deuteromycota: Hyphomycetes) and boric acid against the German cockroach (Dictyoptera: Blattellidae). *Biological Control* 23: 296–302 (<http://www4.ncsu.edu/~coby/schal/2002ZurekBioContMetarhizium.pdf>).

⁶ Mukha D. V., A. G. Chumachenko, M. J. Dykstra, J. Kurtti and C. Schal. 2006. Characterization of a new densovirus infecting the German cockroach, *Blattella germanica*. *Journal of General Virology* 87: 1567–1575 (http://www4.ncsu.edu/~coby/schal/2006MukhaJGenViro187_1567.pdf).

⁷ Zurek L., J. C. Gore, M. S. Stringham, D. W. Watson, M. G. Waldvogel and C. Schal. 2003. Boric acid dust as a component of an integrated cockroach management program in confined swine production. *Journal of Economic Entomology* 96: 1362–1366 (<http://www4.ncsu.edu/~coby/schal/2003ZurekJEEBA dust.pdf>).

⁸ Gore, J.C., L. Zurek, R.G. Santangelo, S.M. Stringham, D.W. Watson and C. Schal. 2004. Water solutions of boric acid and sugar for management of German cockroach populations in livestock production systems. *Journal of Economic Entomology* 97: 715–720 (<http://www4.ncsu.edu/~coby/schal/2004GoreBASwineJEE.pdf>).



Figure 3. Insecticides. Top and middle: Bait dispenser for delivery of boric acid-sucrose solution to cockroaches. Bottom: Adult female German cockroach sterilized by the effects of an IGR.

Outcomes and Successes from an Established Extension IPM Program

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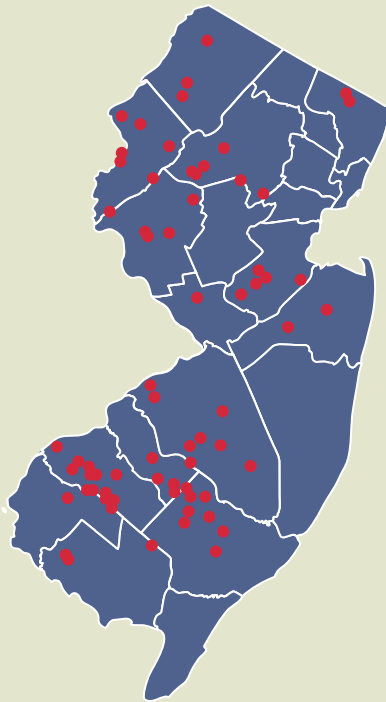


Figure 1. NJ fruit IPM participants.

Program Structure

The NJAES/Rutgers Cooperative Extension Fruit Integrated Pest Management (IPM) Program represents a team approach to helping New Jersey fruit growers produce fruit and manage pests in an economically sustainable fashion, while using multiple technologies to manage pests and minimize pesticide use where possible. IPM program staff combine with specialists and county agents to provide an educational delivery program, driven by current research in New Jersey and other states. The program is supported by state funds, federal competitive grants, and grower/industry fees.

Core program delivery staff consists of a statewide agricultural IPM agent, and three full time program associate staff housed in counties with fruit production and a county agent with fruit responsibility. Unlike extension programs in most other states, our program centers on the weekly delivery of farm scouting information to the commercial grower. Program staff focus on insect and disease scouting, weeds (program dependent), management recommendations, grower communication, sampling for fertility management, and weekly newsletters. Recommendations are in written reports, faxes, emails, or one-on-one discussion. Monitoring data is summarized for weekly articles in extension newsletters and Web presence, grower updates and annual meetings. This structure permits reaching growers throughout the state (Figure 1)

Researchers and subject matter Extension Specialists provide back-up for seasonal issues, assist in staff training, and conduct IPM research from which results are used within the delivery program as recommendations, monitoring procedures, or other knowledge required for successful management. The program represents a two-way approach where delivery staff (IPM Program) share on-farm information, and collaborate on research projects, which results in improved research and overall extension programming for clientele. County based agricultural agents interface with their growers, and provide expertise on plant growth regulators, fertility management, and other horticultural practices that may impact IPM decisions. This model permits measurable outcomes and impacts (Figure 2).

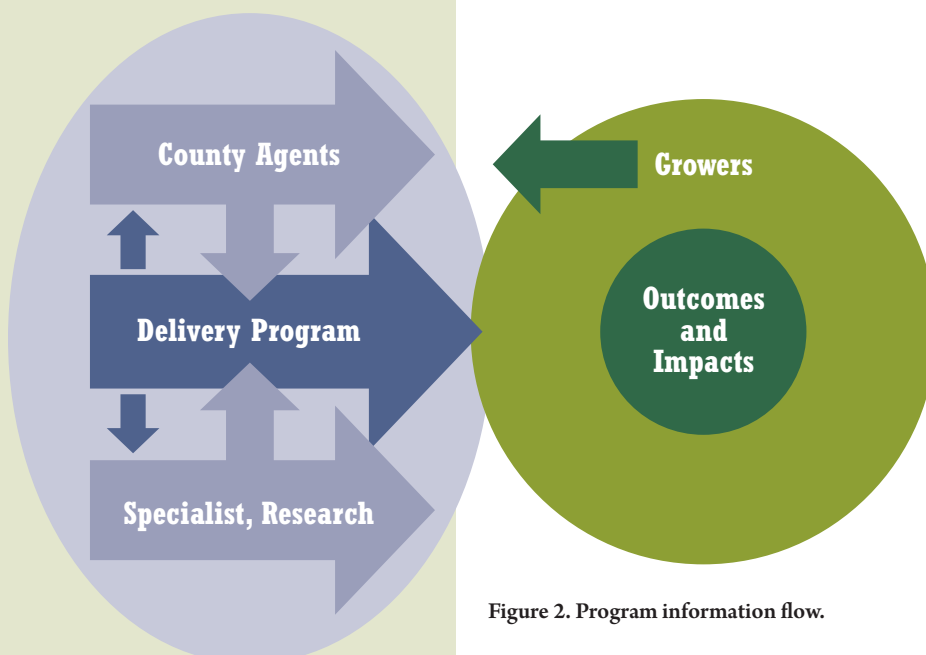


Figure 2. Program information flow.

Grower participation is at two levels. Primary participants have all or part of their acreage enrolled in the program for scouting and recommendations; get IPM reports, fruit quality analyses, tailored fertility recommendations, and end of year pesticide use reports. All fruit growers can get newsletters, attend meetings, or receive emails and faxes where IPM information is summarized and discussed with general recommendations. Secondary participants are all other growers getting IPM information, but not enrolled in the scouting program.

During 2011 the fruit IPM program worked with 88 growers as primary participants, consisting of 41 blueberry growers, 41 tree fruit growers, and 6 wine grape producers. Participating farms made up 66% of total New Jersey blueberry acreage, and about 85% of total peach and apple acreage.

The program is information intensive. Fruit growers now rely on narrow spectrum and expensive pesticides that must be timed for specific pest stages and managed to avoid pest resistance. This means growers must know more about the biology of pests, make use of pest levels and treatment thresholds, insect and disease degree day phenology models and other environmental monitoring tools, various pheromone technologies, and have knowledge of beneficial insects and biological controls.

The recent arrival of two invasive species, the brown marmorated stink bug, and the spotted wing drosophila are refocusing program efforts to the more intense control tactics that will have to be used for these insects. Increased collaborative research efforts will be required over the next 3-5 years with multi-state, multi-crop efforts to manage these pests.

Grower Responsibilities and Impact Measurement

All growers must agree to help the program profile their farm, keep open communication lines with respect to pest control practices during the growing season, and supply a pesticide spray record at the end of the season. All primary participant farms are GPS mapped which includes the crop, acreage, variety and field identification. All seasonal pest levels can be linked to individual fields/blocks, as can the resulting pesticide use. Pesticide use can be compared to grower practices, such as application type, use of mating disruption, or pesticide type and amount, or frequency and number of applications. As a teaching tool, a standard suggested retail price for each pesticide is linked to pesticide use to demonstrate to growers their comparative pest management cost inputs. These factors can be measured over a wide area, for individual farms, or by block or variety. For example Figure 3 shows comparative insecticide use on one farm in peach blocks under standard insecticide use vs. mating disruption.

Figure 3. Pesticide use summary for mating disruption vs. insecticide use, late peaches—grower A.

Insecticide	Standard	Mean Deviation	% Difference
Prod (lb/A)	5.13	1.84	35.9
Active Ingr-ai (lb/A)	2.86	1.19	41.6
Cost/A	48.99	21.6	44.1
Carbamate (ai/A)	0.67	0.61	91.0
OP (ai/A)	2.19	0.58	26.5
Pyrethroid (ai/A)	0	0	—

Other Examples for Measuring Impact

On-farm reduction of insecticide use for blueberry maggot in highbush blueberries:

Due to a “0” tolerance in shipped fruit, blueberry maggot has been the insecticide driver in New Jersey blueberries, often requiring weekly applications from

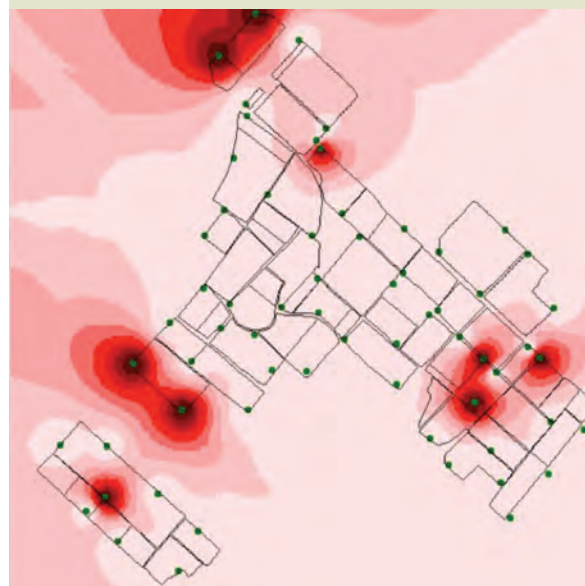


Figure 4. Total seasonal blueberry maggot trap capture, surface interpolation (Arcview 3.3).



mid-June through late July. Placement of geo-referenced traps has resulted in identifying areas of maggot activity and the ability to locate individual insecticide applications. In figure 4 darker areas represent areas of higher cumulative trap catch. Traps (green dots) with no surrounding red represent a “0” seasonal trap total.

Tracking insecticide use by an industry for a specific pest: Through tracking seasonal pest levels and recording pesticide use for all program participants, insecticide use can be focused within a time period for the materials used targeting a specific pest. In figure 5, the percentage of total use of each chemical is listed for use when aphids were the primary target in New Jersey highbush blueberries in 2010. Provado (2276 acres), a neonicotinoid was the leading product, followed by Assail (1187 acres). Knowing overall industry use of specific products allows us to make adjustments and forms a basis for changes that may be required as new invasive species (spotted wing drosophila and brown marmorated stink bug) become more common.

Summary

Over the years we have found that collection of grower acreage, practice, and pesticide use data, not only has helped measure program impact, but also helps adjust and optimize extension recommendations. Knowing what practices and materials growers use, how they use them, and how they perform, helps minimize pesticide use and helps extension with writing statewide recommendations.

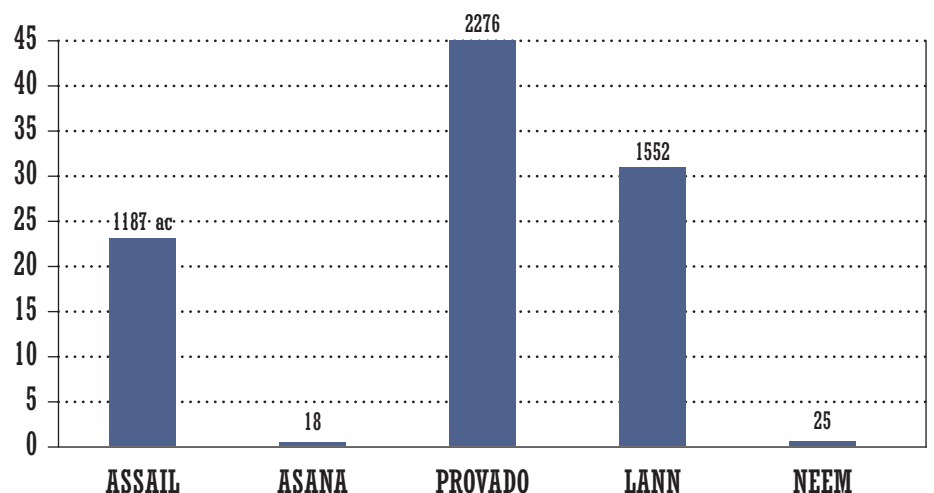


Figure 5. Percent of products used to cover aphids in New Jersey blueberries 2010.

Enhancing Capacity for IPM Practice and Assessment in Arizona

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Measuring and communicating environmental, economic and social impacts of IPM are key to recruiting and leveraging support for our IPM programs, and to maximizing future impacts. Arizona IPM programs are planned, developed and implemented by teams organized under the Arizona Pest Management Center (APMC). Our major areas of emphasis are in vegetable crop IPM, agronomic crops IPM, community IPM and IPM assessment. *Our programs are highly leveraged through federal and state grants and partnerships to maximize impact of our IPM programs.*

For FY 2010 we secured about \$1.1 million in competitive grants and other resources directly related to IPM research and outreach. This included over \$900,000 in federal grants, \$37,200 in Western IPM Center grants, over \$98,000 in state grants, and nearly \$60,000 in other resources.

We have made major investments in IPM assessment, which are paying dividends in increased capacity to document program impacts (Fig. 1). The IPM Assessment Leadership Team, which includes dedicated faculty (IPM Program Manager & an Assistant in Extension) partially funded through EIPM, oversees development of evaluation data and documentation of IPM outcomes and impacts for all program areas. Two main sources of data inform assessments for our agricultural IPM programs. The first of these is a long-standing Crop Pest Losses and Impact Assessment stakeholder

Arizona Pest Management Center—Impacts

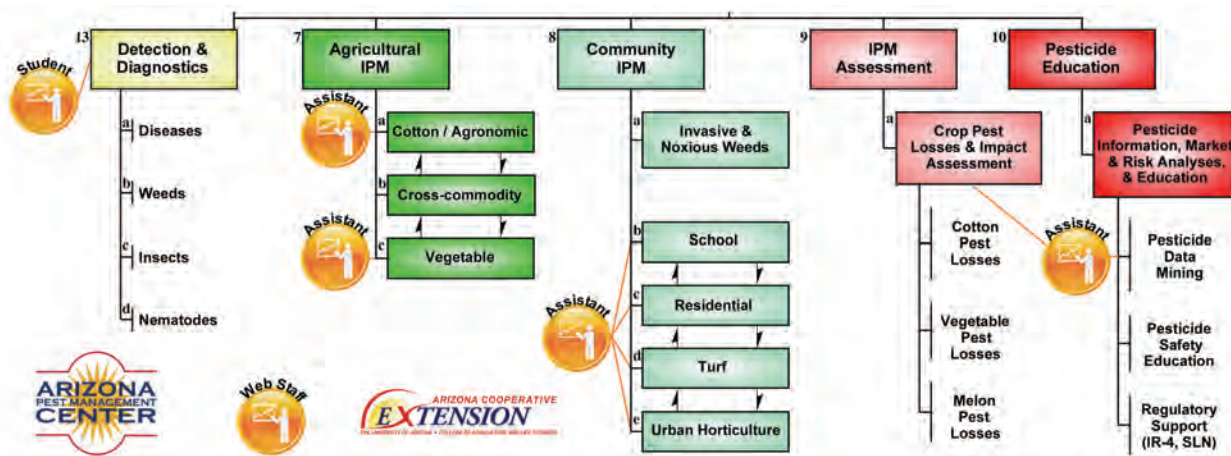


Figure 1. The Arizona Pest Management Center invests resources into formal focal areas of IPM Assessment & Pesticide Education that help us develop quantitative and qualitative measurements of stakeholder behaviors, including the establishment of a 20-yr historical Arizona Pest Management Center Pesticide Use Database, a 32-yr Cotton Pest Losses Database, & a 10-yr Vegetable Pest Losses Database. Orange assets are 50% leveraged through EIPM dollars.



work group funded by the Western IPM Center to conduct surveys of pest control advisor practices on key crops (cotton, lettuce and melons) in Arizona and arid regions of southern California. End-users quantify the impact of insect, weed and disease pests on crop yields and economic outcomes and also provide data on pesticide use, pest trends and emerging IPM needs (Fig. 3). A second, complimentary resource is the Arizona Pest Management Center Pesticide Use Database developed in partnership with Arizona Department of Agriculture and supported through a series of Specialty Crops Block and other grants. The database contains over 20 years of use reports integrated with other resources such as EPA product look-up tables. Our analyses indicate dramatic reductions in the use of most broadspectrum insecticides and rapid adoption and increased use of reduced-risk chemistries for insect pest management in cotton and lettuce (Figs. 2 & 4). For example, Arizona cotton growers have reduced broadly toxic insecticide inputs by 74% compared to pre-2005 levels, much of this due to grower implementation of Lygus management recommendations developed and extended as a collaborative EIPM / USDA–Risk Avoidance Mitigation Program (RAMP) effort. Our cotton IPM program, including adoption of Bt cotton and whitefly-specific insect growth regulators since 1996 and a selective Lygus feeding inhibitor since 2006, has reduced risks to human health and the environment by eliminating over 1.6 million pounds of insecticides annually. Cotton's contribution to the Arizona economy includes 9,000 jobs and \$700 million in 2011.

We have also documented IPM impacts in urban environments. The Community IPM team has helped Arizona's participating schools to reduce pesticide applications an average of 71% and pest complaints by 78%. Over 775,305 residents and thousands more tourists tee off each year for nearly 12 million rounds of golf in Arizona. Active children

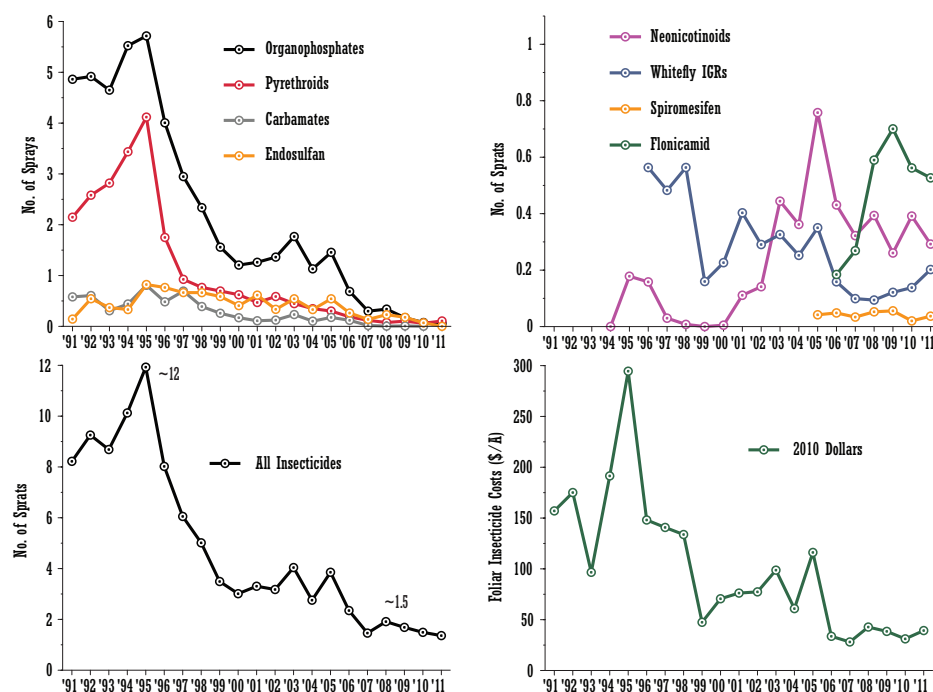


Figure 2. Statewide average cotton insecticide use patterns in Arizona, 1991–2011. Broad spectrum & reducedrisk insecticides (upper left & right) in use during this period. All insecticides & their costs (including application costs) (lower left & right) reached a 33-yr low over the last 6 years. Comparing the last 5 yrs to 1995 (an all-time high), pyrethroids have been reduced by 97%, organophosphates by 95%, carbamates by 97%, and endosulfan by 82% with an overall reduction of cotton insecticide use of 86%. By 2011, 88% of all cotton insecticides were either fully (61%) or partially (27%) selective and safer for natural enemies. Source: APMC Pesticide Use Database & Cotton Insect Losses Database, Arizona Pest Management Center, Ellsworth & Fournier, unpubl., Ellsworth et al. 2009.

and athletes play on turf at home, parks, and on professionally managed sports fields. By showing turf managers where and when their uses of insecticides are unnecessary or ineffective, the elimination of up to 2–3 sprays each year has been possible. This lowers risks of human exposure to pesticides and increases value of leisure industries that generate over \$3 billion to the local economy.

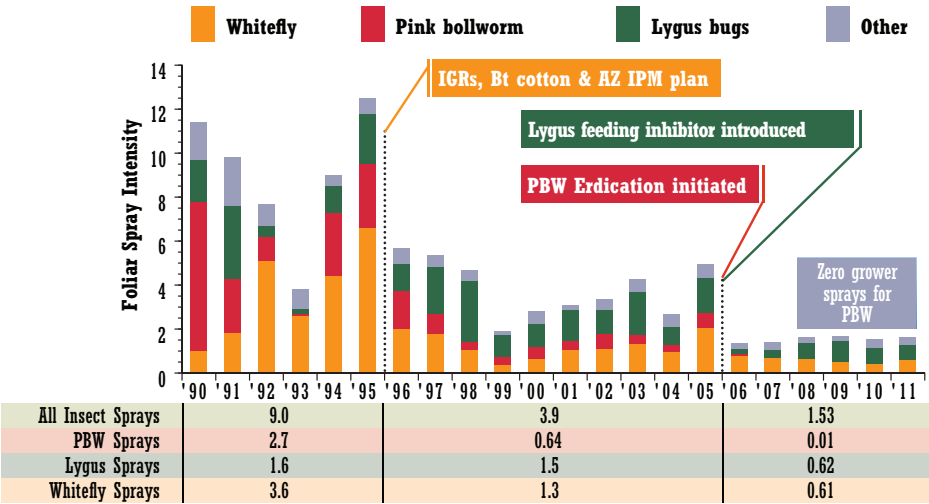


Figure 3. Statewide average cotton insecticide use patterns in Arizona, 1990–2011, by key pest. Over 1.6 million lbs a.i. annual reduction in the last 6 yrs compared to the 32-yr high in 1995; est. cumulative savings in control costs & yield in excess of \$237M. Source: Cotton Insect Losses Database, Arizona Pest Management Center, Ellsworth et al. 2009.

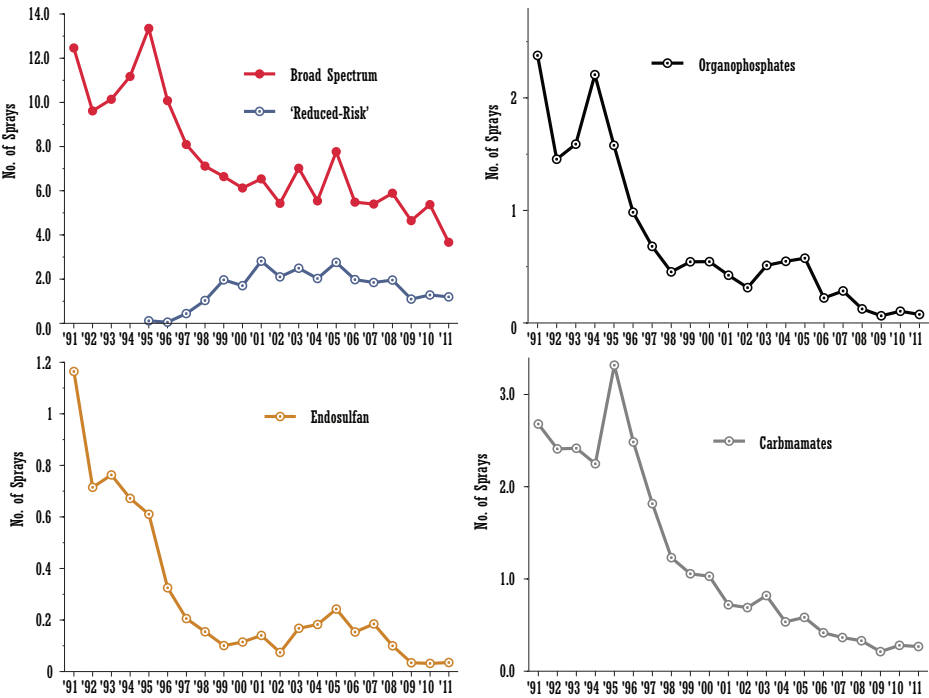


Figure 4. Statewide average lettuce insecticide use patterns in Arizona, 1991–2009. Broad-spectrum insecticide use has declined 66% from a high of over 13 sprays (1995) to less than 5 sprays over the last 3 years; reduced-risk insecticides have increased 10-fold over this same period (upper left). Large declines in key broad-spectrum insecticides have been seen for organophosphates (–95%, upper right), endosulfan (–94%, lower left) and carbamates (–92%, lower right). Source: Pesticide Use Reporting Data, Arizona Pest Management Center, Palumbo et al., unpubl.

