Cornell University
Cooperative Extension

Lake Ontario Fruit Program

Economic Impact of a three year project entitled: "Evaluating Long Term Risks/Benefits of Area Wide Mating Disruption of Codling Moth in New York."

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Issues/Needs and Audiences:

Apples are produced on 42,000 bearing acres in New York in 3 major zones, Lake Ontario Region, Hudson Valley and Lake Champlain region, according to the 2006 NASS Tree Fruit and Vineyard Survey. In 2010, New York growers produced 1.3 billion pounds (~31M bushels) of apples worth $227 M. The 2007 statistics for apple utilization for NY reported that 47% of 32 M bushels of apples produced, were grown for processing (canned, sauce, or juice) worth $174M mainly produced in the Lake Ontario Fruit Region. Fresh fruit utilization in NY for 2007 was worth $157.8M

In 2005, fruit growers in the Lake Ontario Fruit region began to notice significant worm infestation in apples. Codling moth (CM) was identified as the predominant pest. A survey conducted in 2007 at processing apple receiving stations recorded over 300 truckloads of apples with CM and other larvae detected from almost 80 growers in western NY. Damage increased in 2008 to almost 400 truckloads of infested apples from 110 growers. This is the epicenter of internal lepidopteron (lep) resurgence likely due to development of organophosphate (OP) resistance in the CM population in other states such as PA and VA with heavy lep pressure, and transport of empty but infested bins from processors in those states into western New York.

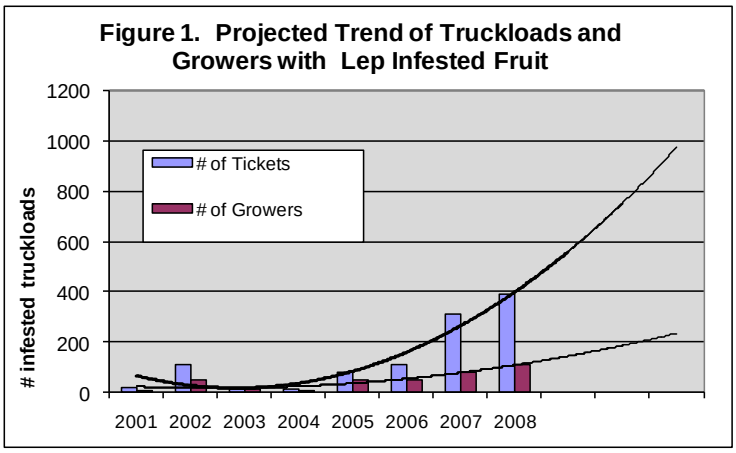
USDA has standards set for several grades of products and fresh apples for tolerance of worms and damage caused by worms. But the markets can and often set lower thresholds for the presence of worms and other insect pests infesting fruit due to discoloration of interior and insect parts potentially contaminating the product. Some processors have a zero tolerance for worms and worm holes which impacts on the destination and value the fruit. The value of apples for premium processing for pie filling and sauce is $10-13 per cwt (hundred lbs) compared to $6.50/cwt for juice. If fruit is found infested, it is diverted from processing to juice resulting in 35-50% reduction in value, $1038-1911 lost per truckload, or an average of $1500 lost per infested truckload. If the grower has consistently "wormy" fruit, he will likely lose his contract for processing apples and his fruit will automatically go to the low value juice market.

Many of the trees on which processing apples are produced are larger and denser, with larger canopy volumes. These orchards are more difficult to spray due to inefficient sprayer size, and growers making

efforts to reduce spray drift. This has contributed to the resurgence of internal lep infestation mainly in the processing industry.

What was the potential economic loss due to internal lep pests?

The trends of infested truckloads of apples in NY have been documented since 2001 when the problem was first noted and are shown in Figure 1. At that time, growers had little experience with the use of pheromones for mating disruption, and had only 2 classes of insecticides to address these insects – organophosphates and pyrethroids. Growers and consultants also had little understanding of the critical timing of insecticide applications under these high populations. **<u>If growers had not made any changes in their practices</u>** with codling moth waiting in the background, a more serious resurgence would have resulted.



The projected trend in Figure 1 was based on a binomial regression and would have climbed from 390 infested truckloads in 2008 to 950 in 2011. Table 1 shows this could have been a loss in fruit value delivered to the processors of almost $3.3M if you assume an estimated $1500 loss in processing apple value if diverted from canners and sauce to juice. This kind of loss was certainly documented in Pennsylvania peaking at 818 loads in 2004, 7 years after the problem was identified, before new insecticides were available, and before mating disruption pheromones were implemented.

These are theoretical projections, based on the assumptions that if growers continue to use the same strategies, insecticides, and timings for control of internal leps that are resistant to organophosphates, the percentage of damage in each farm will increase and spread to neighboring orchards. Since many growers use shared processor bins that can harbor overwintering codling moth larvae from the previous season from another farm, these insects would have spread across the industry with a projected loss of $3.3 M over a 3-year period.

The fresh apples produced are also at risk but damage can be picked off the packing line and reduce the risk of consumers being exposed to “wormy” apples. When a fresh block yields 1,000 bushel per acre and is stored in CA with typical treatments and then run over a packing line, growers will lose $352 per acre for 3.0% damage. This was calculated using market prices of $20/box for count fruit, $16/box for bagged fruit and $2.52 return on culled fruit for juice. A 5% loss would be $587 per acre; and a 10% loss, $1,174 per acre. These losses would be higher when the fresh apple price is higher for a particular variety. If a wormy apple should be discovered in fresh exported fruit, the losses would be much greater as the export market would likely be eliminated for the year and perhaps for years to come.

Extension Response

Cornell Cooperative Extension (CCE) responded to this situation through several strategies. First, CCE identified the primary pest species detected in infested fruit at receiving stations. We collected the larvae found, identified them, documented the delivery ticket number and grower, with the number of infested fruit in the 100 lb. sample. This information was summarized and provided to each grower so they could make pest management plans for future seasons and minimize damage by these pests. The data was summarized each year to determine if the problem was increasing or decreasing.

CCE-LOF applied for funds from NECRME to cover costs of maintenance of the regional pheromone trap network, monitoring traps in the area-wide mating disruption sites, conducting the fruit evaluations before and at harvest for insect damage, collecting spray records, and analyzing data for reports for growers. This data was used to analyze the risks and benefits of the new technology for managing internal lep pests so growers could make a decision as to which strategies would be best for their farms.

Special workshops focusing on internal lep management were conducted in classroom and in the orchard to show and tell growers and consultants about steps needed to manage the risk of fruit infestation. Growers and consultants learned how to identify the pest and damage, how to trap for adult moths, how to use the insect development model based on degree-day accumulation after moths started to fly, how to choose insecticides for control, how to choose and implement mating disruption (MD) pheromones that were new to the market, and how to check the results of spray coverage by their sprayers in trees that are often larger than fresh fruit orchards and more difficult to treat uniformly from top to bottom. This same information was included in newsletters, faxes and emails at specific timings that were critical for control of these pests. Results of the project were shared at summer field tours and winter fruit schools.

A trap network was set up on 25 farms along the Lake Ontario fruit region to monitor adult activity, especially in problem orchards. Weekly trap data was reported to the growers and published on the website for the regional fruit extension program. The first moth caught in pheromone traps, first sustained catch, was reported and included as a biofix date to initiate the degree-day model accumulations to predict best spray timing in each site.

The on-farm “Area-Wide” mating disruption demonstration using pheromones was conducted on 150-acres of relatively contiguous orchards typical of western NY apple production with 4 main growers and a consultant who worked with the growers. Other growers who had high populations of codling moth, but did not want to implement mating disruption, also cooperated; we maintained traps and monitored degree-day information to assist them to identify the best spray timing. In smaller orchards with high populations of internal lep pests, “hot spots,” we tried mating disruption in one location and compared that to infested orchards on the same farm without mating disruption.

Growers and project leaders collaborated on best spray timing and insecticide choices. The first season, however, as technology in pheromones was developing and labor was limited to install hand-applied dispensers at a rate of 200 per acre. Therefore, these processing growers opted for the sprayable pheromones. But the subsequent season, most pheromone product used as in the “Puffer” dispenser that would sprits aerosol pheromone in the tree tops, hung at a rate of 1 per acre, reducing labor required. The Puffers maintained a consistent effective plume of pheromone which is not accomplished using sprayable formulations susceptible to weathering with rainfall.

Economic analysis:

We gathered spray records and costs related to codling moth control and conducted partial budget analysis. After the third season, a net present value analysis was conducted in high pressure orchards with and without the use of mating disruption to get these pests under control.

The cost of planting a new orchard ($6,800 - $13,000 / acre), whether for fresh or processing is significant, therefore the price growers receive for their fruit and the marketable yield is critical in determining what year a grower will recoup his investment in the orchard. Under low prices a new processing block will take more than 30 years to recoup investment, while it commonly takes 15-18 or more years for a new fresh block to recoup investment. Two process varieties, Cortland and Idared were compared at two yield levels (900 & 1,212 bu./acre and Cortland at $10/cwt process with $6/cwt juice vs. Idareds at two fruit price levels ($11 vs $13 / cwt for processed fruit and $7/cwt for culled apples (juice).

We compared how net cash flow was affected for the three years (yrs 11-13) following the initial year (year 10) of the codling moth infestation for both treatments using mating disruption against a more traditional chemical approach. This comparison did not consider the time value of money.

We also compared how the two approaches affected the overall profitability of the orchard using a discounted cash flow, the accumulated net present value (NPV) of profit at a 5% discount rate by year 13. This method takes into account the time value of money.

Accomplishments and Impacts

Due to the extension activities of this project and registration of new insecticides, codling moth/oriental fruit moth infestation of apples did not increase to the projected levels, but actually decreased to a stable level from the peak in 2008 to 225 in 2011 accounting for approximately 3% of processing fruit.

The projected savings in processing fruit value for growers from 2009-2011 was as much as $2.2 M due to this educational project and changes growers made in managing internal lep pests. This is illustrated in Table 1 by projecting the trend of infested truckloads, subtracting the actual infested truckloads, multiplying the difference by $1500 per load to calculate the "processing fruit value saved for years 2009-2011. A more conservative projected savings in fruit value could be estimated by using the peak infested truckload count of 390 in 2008, and subtracting the actual load count for subsequent seasons. This would be a reduction of 497 truckloads of apples over the 3 year period with a value savings of $745, 500. The $150,000 invested in this project, therefore, resulted in a return of 5-15 times the investment for the NY fruit industry.

The fruit industry, however, is not in a vacuum and this project coordinated by Cornell Cooperative Extension is not the only factor in the picture. The industry did make gradual changes as the new technology was registered for use. New insecticides were registered that were more effective than organophosphates and pyrethroids. But this project facilitated on-farm demonstrations for the new technology, and publicized the results to the whole industry so other growers with serious fruit damage could see the results and weigh the risks and benefits of using or not using the mating disruption technology.

Table 1. Fruit Value Saved Using Projected vs. Actual CM infested truckloads delivered to processors.

	2007	**2008**	**2009**	**2010**	**2011**
Projected trend of infested truckloads (% of total)			**550 (7.0%)**	**700 (9.7%)**	**950 (13.0%)**
Actual infested truckloads (% of total)	**313 (4.1%)**	**390 (5.3%)**	**208 (2.7%)**	**240 (3.3%)**	**225 (3.1%)**
Fruit Value saved $			**$513,000**	**$690,000**	**$1,087, 500**
Total Processing Fruit Value saved $ from 2009-2011					**$2,290,500**

Pheromone trap network:

There was great variability demonstrated in the regional trap network for CM flight patterns during the season from one farm to another resulting in initiating degree-day models as much as 2 weeks apart. Trap data also showed an extended first generation flight significantly later in high pressure orchards requiring additional insecticides for the control of the first generation compared to low pressure sites where 1-2 insecticides were sufficient. The variability reported in the trap network encouraged consultants to hang pheromone traps at problem farms to better identify the critical time to apply new insecticides on a farm-by-farm basis, improving regional control results. The potential consequences of not adjusting the biofix on a farm-by-farm basis can throw off timing of insecticide sprays by 7-14 days, which can mean the difference between applications at the recommended 10% egg hatch vs. 50% egg hatch. If larvae have already hatched and penetrated into the fruit flesh, the insecticides are not effective in control.

Area-wide mating disruption project:

This project demonstrated the efficacy of mating disruption (MD) pheromone products on the largest contiguous area in New York. Prior to this project tests had been done on 5-10 acre blocks. Although this 150 acre area was a "mini" project compared to others in Washington state and Pennsylvania, the significant reduction in trap catch numbers and fruit damage published in newsletter articles and at field meetings gave growers more confidence in investing in this perceived "expensive" technology. In fact, the growers who were participating in this project were less likely to implement effective mating disruption because the technology is a shift in paradigm from spraying things several times per season to hanging dispensers in the trees once in the season for season long control. The cost-share helped to overcome the barrier of this most expensive treatment of over $100 per acre, when insecticide costs range from $5 – 35 per acre. The cost-share for the pheromones for 3 seasons provided the incentive for growers to work as a team to "clean up" the problem in the neighborhood. Growers upwind from this project (did not receive any benefit of the pheromone plumes from the disrupted area) are still struggling with 10% fruit damage from codling moth (see North West farm in Table 4).

This project demonstrated a significant reduction in moth mating activity as measured by the number of adult moths captured in pheromone traps shown in Table 2. Number of moths caught in pheromone traps was reduced in the second season by over 90%. Table 2 also shows that CM seasonal trap catch around the disrupted area was reduced by 90% in the standard strength L2 lures. Although oriental fruit moth (OFM) was not a major pest in this project, the trap data shows significant reduction in trap numbers after the pheromone for OFM was included in the Puffer formulation in 2010 and 2011. The trap numbers were significantly reduced where OFM pheromones were used compared to plots without mating disruption as shown in Table 3.

Growers and consultants have increased reliance on more accurate insecticide timing models relative to weekly trap reports. They have found that if traps exceed 5 moths per trap, fruit damage is likely and insecticides should be applied approx. 200-250 DD after the first moth capture. They have learned that controlling the first generation will increase the success of control of later generations and prevent worms in fruit at harvest.

Integrating pheromones for mating disruption and monitoring adult moth activity, with new insecticides and better timing targeting newly hatched larvae has significantly reduced damage from 14% to 0.1% damage and .05% apples infested with worms. The plots without MD that were generally downwind from the pheromone treated area experienced trap count reduction and some reduction in damage. The Northwest – no MD plot was a new addition in 2011 harvest evaluation to see how bad the damage

could be with just insecticide application. This block was northwest of the pheromone plume, and more than .5 miles from the area-wide project with no interference of CM mating activity.

Table 2. Seasonal codling moth trap totals per trap.
2007 had >200 codling moths per trap using standard lure.

	2008	2009			2010		2011	
Farm	CM 10X	CM L2	CM 10X	CM-DA	CM L2	CM-DA	CM L2	CM-DA
Apple Hill - **MD**	**154**	**9**	**5**	**17**	**1**	**23**	**2**	**9**
Long View N - **MD**	**172**	**7**	**15**	**27**	**11**	**29**	**10**	**33**
Long View S /Hill Top - **MD**	**161**	**14**	**16**	**44**	**2**	**10**	**0**	**10**
McKeon - **MD**	**97**	**11**	**9**	**22**	**1**	**7**	**0**	**11**
No MD –avg CM L2	**141**	**58**	**nd**	**nd**	**18**	**nd**	**47**	**nd**

Table 3. Seasonal OFM trap totals.

Farm	**2008**	**2009**	**2010**	**2011**
Apple Hill	**40**	**23**	**6 ****	**1 ****
Long View N	**56**	**44**	**7 ****	**4 ****
Hilltop	**33***	**6***	**1 ****	**1 ****
McKeon	**38**	**20**	**4 ****	**1 ****
No-MD-avg	**155**	**133**	**104**	**76**

* Partial farm disrupted for OFM
** Whole farm disrupted for OFM

Growers and consultants have learned to use more effective, but low environmental and worker risk insecticides for these pests, reducing reliance on less effective pyrethroid and organophosphate insecticides. NY Department of Environmental Conservation registered Assail for use in 2005, Calypso in 2006, Delegate late in 2008 for the 2009 season, and Altacor late in 2009. The addition of these new, but expensive insecticides played a large part in improving control of internal leps.

But growers with high populations of internal leps have not been successful in eliminating injury to the 0.1% level with just insecticides. In fact, if spray coverage is inadequate because of a dense canopy, damage levels can still be significant as shown in the spray coverage results documented in this project. See Table 5. The treatments included no pruning, a standard pruning method of heading and thinning cuts to open tree canopy, and palmette (narrowing the top of the tree canopy by removing 2 main branches growing into the row middles). Processing orchards are not always pruned every year due to high cost of labor and limited labor availability. The most lep damage was noted in the top of the unpruned treatments and numerically higher (but not statistically different) in the grower standard compared to the palmette treatment. Since most of the damage does occur in the tops of the trees, this

project showed how critical it is to get good insecticide coverage in the top of the tree canopy. This also explains why there is less damage noted in fresh fruit orchards that are pruned annually for light penetration into the tree canopy for fruit color development. The area-wide MD demonstration showed how pheromones installed in the upper canopy of the processing trees can overcome some spray coverage issues.

Table 4. Total % CM/OFM damage (deep + stings) and % fruit with larvae.

	2008		2009		2010		2011	
Farm	% Damage	% Worms	% Damage	% Worms	% Damage	% Worms	% Damage	% Worms
Apple Hill - **MD**	2.7	0.38	0.2	0.02	0.2	0.09	0.1	0
Long View N - **MD**	1.4	0.04	0	0	0.2	0.12	0.1	0
Long View S /Hilltop FF - **MD**	2.5	0.27	0.1	0	0.1	0	0.1	0
McKeon- **MD**	2.9	0.33	0	0	0	0	0.1	0
South East – **no MD**	0.8	0	0	0	0	0	0.2	0
North West – **no MD**							10.4	0.8
North – **no MD**	19.0	8.0	3.6	0	0.6	0	nd	nd
Unsprayed	nd	nd	nd	nd	29	13.4	37.5	5.5

Table 5. Fruit damage by codling moth comparing top and bottom of tree canopy among different pruning treatments in high pressure orchard.

Treatment	Top Mean	Bottom Mean
Unpruned	12.1 A	1.2 A
Grower standard - thinning	3.5 B	2.4 A
Palmette	0.6 B	1.2 A

Growers who tried MD in smaller orchards on their farms with high CM populations and damage, essentially cleaned up problems the first season, compared to the blocks without MD. Table 6 shows one farm as an example of many, with and without MD used in the 2010-11 growing season compared to no MD in 2009. Note the grower suffered 8% fruit damage in ’09 before implementing MD, reducing the damage to zero in 2010 using hand applied dispensers (Isomate TT or Checkmate Duel at 200 per acre) and 3 Puffers (aerosol dispensers) in 2011. The Puffers are very effective in large plots, but the hand applied dispensers are more effective in small plots.

Table 6. Comparison of damage caused by CM in "hot spots" with and without mating disruption pheromones. * = pheromones applied						
	2011		2010		2009	
Grower A	% Total IntLep	% worms	% Total IntLep	% worms	% Total IntLep	% worms
Home Farm	5.2	1.6	4.0	0.6	0.8	0
Off-Farm	1.2*	0.6*	0*	0.0*	8.0	0.2

Spray costs and insecticide application reduction:
In 2008, pheromones plus 5-6 insecticides were required the first season in this heavy pressure site. In 2009, growers reduced insecticide applications to 3-4, reducing material costs targeting CM to $216-250 per acre. In 2010, growers were able to reduce the number of insecticides targeting codling moth to one targeted insecticide for each of 2 generations, and in 2011 they reduced the costs of pheromones by 25-30%, with 1 insecticide targeting CM per generation. Table 7 shows the cost of CM control program under MD and without MD. But note the differences in % damage shown in Table 4 with the lower costs.

Table 7. Pheromone plus insecticide costs				
Spray costs $$	2008	2009	2010	2011
Apple Hill - MD	290	217	182	137
Long View - MD	253	217	172	137
Hilltop FF - MD	---	---	163	137
McKeon FF - MD	290	217	178	137
No-MD plots	155-170	184	118-169	104-133

Economic Analysis:
Although mating disruption adds $100-120 per acre to pest management costs, partial budget analysis revealed that under high codling moth populations on a 50 acre farm, in high yielding processing orchards, growers could easily pay the added cost and make $400-17,000 added profit just by reducing damage and increasing quality/value of the fruit in the first year. There is no added profit for the following years as they do not fit the description of a "high CM" population. But the continued use of pheromones is justified and the added profit the first year will support pheromone costs the next few seasons to further reduce the damage.

The use of mating disruption improved net cash flow over three years from $2,298 for Cortland at 900 bu. per acre and $6,053 improved net cash flow for Idared at the $13/$7 per cwt for processing/juice at a production of 1,212 bu./acre. Six scenarios are presented in Table 8 showing the improved net cash flow and the accumulated net present value of profit using discounted cash flow analysis for year 13 when growers with infested orchards improved fruit quality by using mating disruption. Although processing profitability is not realized until after 20 years, the profitability of all orchards at year 13 improved from $1,270 to $3,364 per acre by using mating disruption over traditional chemical control methods.

Table 8. Difference in cash flow and profitability with improved fruit quality and value for six pricing and yield scenarios.				
Variety	Price/cwt.	Yield Bu./A.	Improved 3 yr. Net Cash Flow	Improved NPV of Accumulated Profit at Yr 13
Cortland	$10 / $6	900	$ 2,298	$ 1,270
Cortland	$10 / $6	1,212	$ 3,141	$ 1,565
Idared	$11 / $7	900	$ 3,054	$ 1,691
Idared	$13 / $7	900	$ 4,460	$ 2,475
Idared	$11 / $7	1,212	$ 4,159	$ 2,308
Idared	$13 / $7	1,212	$ 6,053	$ 3,364

Grower survey:

When 60 growers were surveyed regarding the activities of this project, 14 growers (23%) responded representing 1.2 M bushels of apples. Of respondents, 8 reported moderate to high levels of damage with as many as 10 truckloads rejected or downgraded for juice in 2007, 4 with no damage; but only 4 with moderate to high damage in 2011 with 1-6 loads downgraded, and 8 growers with no damage. Given this data and the worm survey data reported in the trends, this project clearly reduced damage from these pests.

When asked how this educational project impacted their farm, growers' responses follow:

- We added additional sprays at different times to compare impact on internal leps.
- The program had a very positive impact - we know that the technologies that are being tried are working for control of internal lep.
- It made me be more aware of trap counts and more conscientious.
- This project greatly increased the control of the internal lep pests. The spray process understanding was very helpful. I was grateful that this farm was chosen to participate.
- It helped me understand pheromone disruption.
- I gained further knowledge of internal leps and procedures/options to gain control.

When growers were asked what other impacts on their business they experienced when there was internal lep damage in their apples, they listed the following all of which add up to lost revenue:

- We increased scrutiny when hand thinning fresh fruit and did more sorting at harvest.
- We would arrange fruit to go to markets that had higher tolerance for worms.
- We applied extra sprays and sprayed more with newer class chemicals to keep impact under control.
- Four growers reported crop loss, reduced prices, loss of income, increased financial burdens, and lowered packout for fresh apples.
- Growers who have not responded to increasing internal lep damage have lost their market.

What sources of information did industry use to determine changes?

Information regarding the project results and managing internal leps was disseminated through various media. Of respondents, 71% used the extension newsletters, semi-weekly fax/email subscriptions, and their private consultant; 43% used a chemical sales representative. The most useful in order of ranking were the semi-weekly fax/email updates from extension, extension newsletter updates, working directly

with an extension educator, winter fruit schools sponsored by extension, and on-farm demonstrations conducted with consultants, growers, and extension. Information distributed through websites was not reported as useful to these respondents.

What changes did the industry adopt?
The first changes 21% of respondents made when they discovered damage from internal lep pests were to implement pheromone trapping and monitoring for these pests; others scheduled insecticide applications based on degree-day models; 14% implemented mating disruption pheromones, and one grower reported increasing gallons per acre of water applied when spraying to improve spray coverage. The second change 29% of respondents made was to adopt mating disruption in high pressure areas and spot insecticide treatments; and 21% added more insecticide applications and chose new insecticide chemistry. In 2011, 93% of respondents incorporated new insecticides and relied less on pyrethroids and OP's for control of internal leps; 93% of growers used trap data to assess the need for sprays and 64% knew they used degree-day timing models to schedule insecticides. In 2012, 100% of respondents plan to use trap data, 64% plan to use degree-day models, 79% plan to use new insecticides, 43% plan to use mating disruption in orchards with high populations of CM/OFM.

As success of this project has been promoted across the industry, mating disruption increased in usage from a few small demo plots in 2007 to over 2000 acres in Western NY in 2010 used by more than 25 growers with high codling moth populations. If not for the additional funding of the on-farm demonstrations and original grower stipends in form of pheromone products or cost sharing, growers would not have been willing to invest the $100 of additional cost of control in this new, unconventional, technology for pest management. Although growers will not likely choose to incorporate pheromones into an annual program after damage has subsided, it will remain an important, effective, economical tool for growers with damage for years to come.

Collaborators:

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