“We conducted an educational project funded by the Northeast Center for Risk Management Education/USDA to help growers reduce the economic and environmental risk of codling moth and oriental fruit moth management. This project has demonstrated that if mating disruption is implemented on a multi-year basis, insecticides specifically targeting Codling Moth can be applied as recommended for “low” pressure orchards with one spray per generation. Pheromone application rates can be reduced by 25% on a case by case basis.”

In 2005, fruit growers began to notice more worms and worm damage in fruit at harvest. There was a significant shift from oriental fruit moth (OFM), the prevalent internal lepidopteron (lep) larvae noted in 2002, to codling moth (CM) in 2005. A survey conducted in 2007 at processing apple receiving stations recorded over 300 truckloads of apples with CM and OFM larvae detected from almost 80 growers in western NY. Damage increased in 2008 with almost 400 truckloads with infested apples from 110 growers. Growers lose approximately 50% of the value of their apples at the processor if they are too “wormy” for canners and sauce and consequently diverted to juice.

Agnello (2009), Breth (2010) and consultants around the region were trying various mating disruption pheromone products available in apples to control these pests in 2006 with many small demonstration plots of 5-20 acres of apples. However work done in Michigan and Washington showed increased success when mating disruption was deployed on a larger scale. Thus our team began an educational demonstration project in 2008 to manage the economic and environmental risk of internal lepidopteron larval infestation of apples on a larger scale with growers who had suffered serious losses due to these pests.

Three contiguous farms were identified and they agreed to participate in the first large-scale demonstration of mating disruption pheromone technology in NY to control codling moth. In 2007, these farms had over 12% fruit damage caused by internal leps and over 5% fruit with larvae detected.

The project began with a workshop in the orchard to show the various pheromone products on the market. At that time, the 3 products that we had the most experience working with included the hand-applied dispensers from CBC America (Isomate TT CM/OFM) and Suterra (Checkmate Duel dispensers) and the sprayable formulations from Suterra (Checkmate CM-F and Checkmate OFM-F). We had very little experience working with the Suterra Puffers at that time, and the paraffin based droplet application (SPLAT) was not developed sufficiently to consider as an option.

Methods

Pheromone Technology: In 2008, Apple Hill Farms, Long View Farms, and McKeon Fruit Farms identified a 150-acre tract of land with various apple blocks that were as contiguous as commonly found under western NY conditions. Figure 1 illustrates the layout of the orchards by quadrant A-D. Quadrant “A” represents Apple Hill; quadrant “B”, Long View N; quadrant “C”, Long View S sold to Hilltop Fruit Farm in 2010; and quadrant “D”, McKeon Fruit Farm. The area outlined in green identifies the 20-acre portion of quadrant “C” where the Isomate TT CM/OFM were installed in 2009 and 2010, increased from 10 acres in 2008.

The farms produce a mix of primarily process and fresh apples. These growers do not have a large labor pool available early in the growing season to do manual tasks such as hanging hand-applied pheromone dispensers during bloom. Therefore, in 2008, they chose the sprayable pheromones to apply with an airblast sprayer. There was a 10-acre section of quadrant “C” where Isomate TT CM/OFM was installed at bloom at 200 dispensers per acre with the assistance of the grower for the purpose of demonstrating the hand applied pheromones. Pheromones were to be applied at first flight of codling moth, followed up with 2-3 sprays of Checkmate CM-F at 2.5 oz/acre per generation of flight until flight numbers were reduced to less than 5 moths per trap per week.

In 2009, the growers decided to deploy the Suterra Puffers for CM installed at a rate of 1 Puffer per acre with the plan to treat...
border trees with Checkmate CM-F (Jun 3, July 2, and Aug 3). The 10 acre block of Isomate TT CM/OFM was expanded to 20 acres in 2009 with 200 twin tubes per acre applied with assistance from the grower. In 2010, the same pheromone dispensers were incorporated with Suterra Puffers for CM and OFM installed at 1/acre. Isomate TT CM/OFM rates were reduced by 25%, applied at 150 per acre, since experience in other regions has shown success using lower rates the third season if the pest damage was very low in the previous season.

Monitoring: CM and OFM/LAW moth flight was monitored in trap stations set at 3-5 acre intervals (38 trap stations) around the 150 acres. Three trap stations were also placed in nearby orchards to monitor undisrupted populations. We used Pherocon IIB traps and Trece OFM standard lures, hung 5 feet off the ground, and CM 10X lures hung in the tops of trees in 2008. Traps were checked weekly, and counts were reported to growers and illustrated on a kiosk by color coding to report the trap activity in the neighborhood as shown in Figure 4. In 2009, 3 different types of CM lures were evaluated. CM L2 (long-life standard lures), CM10X, and CM-DA Combo lures. CM10X lures release 10 times the rate of codlemone compared to a standard lure and were first used to monitor moth flight in areas under mating disruption. CM-DA combo lures are a combination of a pear ester and a high rate of codlemone reported to be the most attractive lures as they will also attract a small percentage of females. Since the most moths were caught using the CM-DA combo lure in 2009, we eliminated the use of CM 10X lures in 2010, and primarily incorporated CM-DA combo lures hung in the top third of the canopy with some stations supplemented with long-life standard lures (CM L2) hung at 5 feet above the ground.

Insecticide Sprays: Insecticides were chosen based on efficacy for control of CM/OFM and scheduled according to the MSU model for the first generation (200-250DD50F after first flight, plus 10-14 days), and followed up for the second generation based on high trap counts exceeding 5 moths per trap per week.

In 2008, the first generation was generally controlled using Calypso. The second generation egg hatch in August was controlled using Delegate (newly registered in NY in 2008). Any flight activity between those periods was addressed using Proclaim insecticide to target leafrollers, and Assail or Calypso to target late season CM, OFM, and apple maggot. The late sprays in early September were used on later varieties harvested after Cortland.

In 2009, insecticides targeting CM included Calypso or Assail, Delegate and Altacor (newly registered in 2009 in NY) to address egg hatch after high trap numbers. The first generation sprays were Calypso applied according to the MSU model. The remaining season sprays were based on trap catch numbers for the late first generation flight (B peak) and the second generation.

In 2010, we planned the only spray for the first generation of CM egg hatch at 350 DD after biofix (as recommended by the MSU model under low lep pressure) using Calypso targeting CM, OFM, aphids, leafhoppers, and plum curculio or Delegate targeting CM, OFM, and OBLR. The subsequent sprays were applied based on increases in trap catch around the “B”-peak recorded on June 30 also targeting leafroller, and second genera-

| Table 1. Seasonal codling moth trap totals per trap for various lure types for each farm. |
|-------|-------------|-------------|-------------|-------------|-------------|-------------|
| Apple Hill | 154 | 9 | 5 | 17 | 1 | 23 |
| LongView N | 172 | 7 | 15 | 27 | 11 | 29 |
| LongView S /Hilltop | 161 | 14 | 16 | 44 | 2 | 10 |
| McKeon | 97 | 11 | 9 | 22 | 1 | 7 |
| No MD - avg CM L2 | 141 | 58 | nd | nd | 18 | nd |

<p>| Table 2. Seasonal oriental fruit moth trap totals for each farm. |</p>
<table>
<thead>
<tr>
<th>Farm</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple Hill</td>
<td>40</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>LongView N</td>
<td>56</td>
<td>44</td>
<td>7</td>
</tr>
<tr>
<td>LongView S /Hilltop</td>
<td>33*</td>
<td>6*</td>
<td>1</td>
</tr>
<tr>
<td>McKeon</td>
<td>38</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>No MD - avg</td>
<td>155</td>
<td>133</td>
<td>104</td>
</tr>
</tbody>
</table>

*partial quadrant disrupted with OFM pheromone

Figure 2. Isomate TT CM/OFM are installed at 200/acre in the top third of the tree canopy before CM flight in the spring.

Figure 3. Suterra Puffer is installed at rate of 1 per acre in top third of tree canopy.

Figure 4a. Kiosk shows the weekly trap catch report by color coding; red=>10 moths per trap, green=4-10 moths, blue=1-3 moths, white=0. In 2008, there was a lot of red showing.

Figure 4b. Kiosk in 2010 showed fewer high trap counts, most CM caught around edges next to high insect pressure.
tion flight starting on Aug 4, peaking on Aug 25. Based on trap activity in the area, using the trap threshold of 5 moths accumulated per trap, we would recommend Delegate or Rynaxypyr (Altacor or Voliam Xpress) for the second generation. We needed to integrate the control of other pests including leafrollers and apple maggot later in the season.

Other pests were controlled as needed using other insecticides including chlorpyrifos pre-bloom, Proclaim, and pyrethroids. In 2010, to prevent economic damage from apple maggot with reduced insecticide use, we hung maggot traps in early July around the perimeter of orchards in areas of high risk.

**Fruit Evaluations:** Fruit damage assessments were made in July to evaluate control of the first generation. Fruit damage was evaluated at harvest by picking 50 apples from the top and 50 from the bottom from each of 5 trees scattered across the individual blocks of fruit by variety. We evaluated 15,000 to 18,000 apples each year for damage from various insect pests.

**Results**

**Trap Counts:** Tables 1 and 2 summarize the seasonal total CM and OFM adults caught per trap for 2008-2010 for various lure types. In 2008, seasonal total of 150 CM were caught per trap. Trap shut down in 2009 was significantly improved compared to 2008. The comparable lure, CM 10X, caught only 11 moths for the seasonal per trap total compared to 150 the previous year – a 92% reduction. The non-mating disruption counts were reduced from 2008 levels by only 58%. There was also a reduction in the total moth catch in the non-mating disruption sites due to the plume effect downwind. Research reported by Casado (2010) at UC-Berkeley showed suppression of CM male captures 250 ft. wide by 900 feet long from a single Puffer.

Table 2 illustrates the relatively low pressure of OFM in the disrupted area but it remains a significant pest where not disrupted. As OFM pheromone was incorporated in the whole disrupted area in 2010, OFM trap catch was essentially shut down using mating disruption as illustrated in Figure 5. In 2008-09, only the 10–20 acres of Long View S/Hilltop included OFM pheromone for mating disruption.

The CM trap data plotted in Figure 6 using CM10X lures illustrates the poor trap shutdown using the sprayable pheromones. Trap counts using CM10X lures clearly exceeded the 5 CM per trap threshold for 9–11 weeks during the growing season in 2008 using sprayable pheromones. These growers only applied a total of 4 or 5 Checkmate CM-F sprays for the season leaving long periods without saturating the orchard with pheromone in 2008.
But after implementing more stable saturation of the area using Puffers in 2009 and 2010, the scale of Figure 7 was significantly reduced from a peak flight of 38 moths in early August of 2008 to 4 in August of 2010 using CM-DA Combo lures. Trap counts in 2010 never exceeded the threshold. However, we continued to see 3 distinct flight peaks even under low pressure: the “A” and “B” peaks of the moth emergence from the overwintering larvae and the second generation flight in August. The “B” peak (Breth, 2009) is the most common area of weakness in control programs leading to fruit damage.

**Insecticide Use and Cost:** Table 4 shows the cost of pheromones and insecticides per acre targeting internal lep pests. Table 5 shows the number of insecticide applications targeting internal leps. In 2008, pheromones added $100-120 per acre and still required 5-6 insecticides the first season in this heavy pressure site. In 2008, growers spent nearly $300/acre managing CM and OFM. The insecticide choices in 2008 were changed from organophosphates (OPs) and pyrethroids used in 2007, to more costly neonicotinoids and Delegate.

In 2009, growers reduced insecticide applications to 3-4, reducing material costs to control CM to $216-250 per acre. The costs were not reduced significantly since new classes of insecticides are more expensive than older OP’s and pyrethroids, but more effective. In 2010, growers were able to reduce the number of insecticides targeting codling moth to one per generation.

**Fruit Damage Evaluation:** Table 3 shows the overall fruit damage caused by internal lep pests as the sum of % deep and stings damage and the % of apples with larvae detected. In 2008, there was 0.7% deep feeding, 1.8% sting damage, and 0.3% worms in fruit compared to >12% damage and 5% larvae in fruit in 2007. In 2009, there was essentially no deep feeding detected, 0.1% sting damage, and in all of the 18,000 apples, one worm was detected and identified as OFM (which was not under pheromone disruption). The pressure in 2009 was not as high as 2008 due to the cool, wet weather interfering with CM mating activity, however a sprayed orchard without mating disruption in the region had 12% lep damage and 2.6% worms detected indicating sufficient pressure requiring control measures. The conditions for CM activity were excellent in 2010; the unsprayed orchard had 29% fruit damage and 13% fruit were infested with larvae at harvest.

**Economic Risk:** An Excel Workbook was developed to assess the economic risks and benefits of using mating disruption using partial budget analysis. Using mating disruption to improve control of internal lep pests increased cash inflow due to increased fruit value, increased cash outflow with the cost of additional pheromones, and decreased cash outflow by limiting the time and energy used to manage wormy truckloads of fruit. Partial Budget Analysis showed that mating disruption is an economically feasible solution for growers who divert 5-10% of fruit from juice grade to regular and premium grade apples on 50 acres of premium varieties at $12.5-13 per cwt. In this circumstance, the grower increased available cash to a 50-acre operation in the range of $319-17,500 for a single year of mating disruption plus proper insecticide choice and timing. Mating disruption is economically feasible if:

- implemented in moderate to high pressure orchards that typically sustain 5-10% damage.
- used in orchards with moderate to high yield of 750-1200 bushels per acre.
- used in orchards with high value apples with a regular vs. premium price of $12.50-13.00 per cwt (100 lbs.).

This partial budget analysis predicts that if apple prices are less than $11 per cwt, the high insecticide plus pheromone costs in the first year to clean up the population will not break even or result in more cash available. In order to be economically feasible after the first year, the cost of the pheromone and insecticides must decrease in order to break even since the biggest increase

---

**Table 3. Total % internal lep damage (deep and stings) and % fruit with larvae.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Farm</th>
<th>2008 % Damage</th>
<th>2008 % Worms</th>
<th>2009 % Damage</th>
<th>2009 % Worms</th>
<th>2010 % Damage</th>
<th>2010 % Worms</th>
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</thead>
<tbody>
<tr>
<td>Mating</td>
<td>Apple Hill</td>
<td>2.7</td>
<td>0.38</td>
<td>0.2</td>
<td>0.02</td>
<td>0.2</td>
<td>0.09</td>
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<tr>
<td>Disruption</td>
<td>LongView N</td>
<td>1.4</td>
<td>0.04</td>
<td>0.0</td>
<td>0.12</td>
<td>0.2</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Lonview S/Hilltop</td>
<td>2.5</td>
<td>0.27</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>McKeon</td>
<td>2.9</td>
<td>0.33</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Non-Disrupted</td>
<td>South East</td>
<td>0.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td></td>
<td>North East</td>
<td>1.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>19</td>
<td>8.00</td>
<td>3.6</td>
<td>0.0</td>
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<td>0.0</td>
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<tr>
<td>Non-Disrupted</td>
<td>Unsprayed</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>29.0</td>
<td>13.4</td>
</tr>
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</table>
in returns due to the improvement in fruit quality and value will only be significant in the first season. However, growers might consider the increase in fruit value derived from the first season as a resource available to carry the cost of pheromones through subsequent seasons until the problem is rectified.

This project has demonstrated that if mating disruption is implemented on a multi-year basis, insecticides targeting for CM can be applied at timings recommended for “low” pressure orchards with one spray per generation. This project and other trials have demonstrated that pheromone application rates can be reduced by 25% in some cases. The insecticide inputs should only be reduced if there was no damage to fruit detected during the previous harvest, and no damage is detected from the first generation as determined by monitoring of fruit damage in July. Monitoring moth activity with traps is still critical in deciding the intensity of insecticide applications for these pests.

Conclusions
Labor availability and pest pressure are the biggest factors in choosing a pheromone dispenser type. In our project, traps were not zeroed for most of the 2008 season due to: 1) inconsistent saturation of the orchards with pheromone, 2) the tendency of growers to wait until they detected significant CM flight before they applied pheromones, and 3) the delay in waiting until an insecticide was scheduled. Growers also experienced rainfall removing the sprayable pheromone residue. Sprayable pheromones have been successful in other areas with more frequent application but require much more management to achieve control of this pest complex. Better control of CM activity was obtained using more stable dispenser types of pheromone including the Puffer technology and the hand applied dispensers such as Isomate TT CM/OFM.

This project has been successful in reducing trap catch signifying reduced moth activity. When pheromones are used in combination with effective insecticides and the proper spray timing, we have shown a significant reduction in pest damage. Overall, using mating disruption in theory will result in less mating, fewer eggs, and fewer eggs hatching preventing the sting and deep damage. Since this pest builds from generation to generation, from year to year in the orchard, control strategies will need to be intensified as the problem exceeds an economic threshold. But as the pest damage is reduced to a very low level, these pests likely can be treated as a background pest with less intensive management and cost required. The value of mating disruption is clear in cleaning up high pressure orchards that sustain more than 5% fruit damage using a combination of mating disruption and well-timed insecticide applications.

It is difficult to measure the economic value of a grower’s reputation for wormy apples, and how that might impact his ability to maintain a market for fruit. It is also difficult to measure the management time in picking around worm-damaged apples at harvest to avoid fruit rejections or downgrading quality. Only time will tell if mating disruption pheromones will continue to be used for the pest management. Under high pest pressure, and with the potential of insecticide resistance to new insecticides, mating disruption is a very effective tool to manage internal lep pests.

Literature Cited


Acknowledgements
We gratefully acknowledge the technical help of Elizabeth Tee and Ron Faro, Program Assistants for CCE-Lake Ontario Fruit Team and Michael Burlee, Crop Protection Services. We also acknowledge the support of the participating growers and of Art Agnello, Professor, Department of Entomology, Cornell University and Matt Wells, Dr. Pepper Snapple Group, Mott’s. This project was supported by USDA/NIFA under Award Number 2007-49200-03888.

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Alison DeMarree is an an extension educator with the Lake Ontario Fruit Program of Cornell Cooperative Extension who specializes in Economics and Farm Business Management.

Art Agnello is a research and extension professor in the Dept. of Entomology at Geneva who leads Cornell’s apple pest management program. Liz Tee is an extension program assistant who works with Debbie Breth.

Table 4. Pheromone plus insecticide costs

<table>
<thead>
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<th>Orchard</th>
<th>2008</th>
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<td>Hilltop FF</td>
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<td>---</td>
<td>163</td>
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<tr>
<td>McKeon FF</td>
<td>290</td>
<td>217</td>
<td>178</td>
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</tbody>
</table>

*some sprays are not included in this evaluation since they were targeting other pests including PC, OBLR, WAA, and Apple Maggot.

Table 5. Insecticide applications targeting codling moth

<table>
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<tr>
<th>Orchard</th>
<th>2008</th>
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<th>2010</th>
</tr>
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<td>2</td>
</tr>
<tr>
<td>Long View</td>
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<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Hilltop FF</td>
<td>---</td>
<td>---</td>
<td>2</td>
</tr>
<tr>
<td>McKeon FF</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
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</table>
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  509-882-6922