"Final Project Report to the NYS IPM Program, Agricultural IPM 2003-2004."

1. Title:
Implementing Mating Disruption Control Strategies for Oriental Fruit Moth in Tree Fruit

2. Project Leader:
Deborah I. Breth, Lake Ontario Fruit Program, Cornell Cooperative Extension

3. Cooperators:
Drs. A. Agnello, W.H. Reissig, J. Nyrop, NYSAES, Dept. of Entomology; J. Carroll, NYS IPM, Growers in Lake Ontario region, Private consultants and field reps

4. Type Of Grant:
Monitoring, forecasting, and economic thresholds
Training practitioners to use IPM techniques

5. Project location:
Niagara, Orleans, Monroe, and Wayne counties

6. Abstract:
A major educational effort was launched in early 2003 to respond to the increase in internal lepidopteran larvae infestations in apples, peaches, and pears. Several educational events starting with Winter Fruit Schools, a "Worm Management Workshop", field training sessions, and on-farm trainings increased knowledge of growers and consultants to assist in management strategies for internal lep management. The regional trap line to monitor flight of internal lep pests was instrumental in teaching cooperators how to monitor for these pests, and provided realtime flight activity to compare to theoretical DD models under development. Growers and consultants used the flight activity reports to time controls in 2003. The trend of a 3-4 fold increase in rejected truckloads of apples as seen in PA and VA across the WNY region was prevented by the educational efforts taken through this project. The next step is to continue research to find alternative control strategies that are more compatible with IPM programs in apples and peaches.

7. Background and Justification:
Western New York has approximately 28,000 acres of apples, 700 acres of pears, and 1200 acres of peaches. Observations made in apples, pears, and peaches across the region in 2002 showed that internal lepidopteran larvae are infesting fruit at increased economic levels. The primary species are *Grapholitha molesta*, oriental fruit moth (OFM), *Cydia pomonella*, codling moth (CM), and *Grapholitha prunivora*, lesser appleworm (LAW). The number of processing apple loads rejected at processors due to presence of worms increased from 30 loads from 12 growers in 2001 to 113 loads from 48 growers in 2002. Every truckload of apples rejected as canners diverting them to juice reduced their value by $1500 per load (a drop in value from ~ 8 cents for processing apples to juice at ~ 4 cents per pound), if they have a juice market at all.

Scientists experiencing the same problems in other regions suggest possible reasons for the increased infestation by internal lepidoptera include 1) the reduction in the use of broad-spectrum insecticides such as OP's, 2) the development of resistance to those insecticides, and

3) the reliance on more selective insecticides to control other pests in the complex that are not efficacious against oriental fruit moth (OFM) and/or codling moth (CM.

Tools for internal lep management in NY is limited to azinphos-methyl, pyrethroids, phosmet, Avaunt, and mating disruption. Other states also have access to the use of Intrepid and Assail to assit in control of CM and OFM. Mating disruption used in areas on a region-wide scale, has been successful in reducing the population of OFM after a couple of years of mating disruption. We have demonstrated in many orchards that mating disruption for OFM is fairly successful but there are limitations. CM is more difficult to disrupt, and requires very large areas under mating disruption. Orchards with mixed population of OFM and CM are especially challenged since these two pests have different critical timings necessary for insecticide application. OFM has 3-4 generations per season, and CM, 2 generations per season. Although insecticides will still be required in control of OFM, there is potential to minimize pesticide inputs in controlling OFM using proper timing and mating disruption.

In the Mid-Atlantic state, the number of loads rejected due to internal worms has doubled from one year to the next to >600 loads, until growers were able to identify ways to control the problem. Since these insects overwinter in the orchards, the potential is to build on the population from year to year if no steps are taken to intervene. This project was intended to minimize the level of infestation across the region for 2003 using the current research base, while more research is done with a smaller group of growers. This project addresses the consequences of FQPA impending limitations in the use of organophosphates, it demonstrates alternative pest management products, it supports IPM decision support systems, and delivers a management system to the grower community.

8. Objectives:

1) Expand educational programs to implement mating disruption for OFM control
2) Increase the efficiency and publicity of the OFM/CM trapping network.
3) Project Evaluation

9. Procedures:

Objective 1: Expand educational programs to implement mating disruption for OFM control
A "Workshop to Manage Worm Outbreaks in Fruit (OFM/CM)" was held in two sites on March 19, with Cornell faculty, extension, IPM Fruit coordinator, and representatives from companies with NYS registered materials. There were 2.5 NYS DEC Recertification Training Credits accredited to the workshop.

The objectives of the workshop were to:
a) Help growers determine risk of infestation by internal larvae of oriental fruit moth and/or codling moth
b) Assist in identifying appropriate control tactics - using monitoring and models, mating disruption, and insecticide controls

The agenda included:
A Review of Identification and Biology of OFM and CM
Identify Risk of Infestation by OFM/CM to Plan Course of Action
How to Monitor for Internal Leps using Pheromone Traps
How to Use Degree Day Models to Predict Egg Hatch and Time Control Procedures
Relative Efficacy of New and Old Insecticides
How to Implement Mating Disruption for OFM Control

The April workshops were held at Cherry Lawn Farm in Alton, and Toussaint's Fruit Farm in Knowlesville in conjunction with a peach pruning workshop. We taught growers how to hang pheromone traps, number of traps per farm, height and location in orchard. Distributed color fact sheets for identification of CM/OFM/LAW in adult, egg and larval stage and the signs of infestation. Growers volunteered in some areas to maintain traps on their farms.

May workshops were held in conjunction with Petal Fall/Thinning field meetings at Doyle's Fruit Farm in Wolcott, and Newroyal Farms in Lockport. Growers learned to identify moths from imposters in traps and showed signs of infestation from 2002 season. And growers learned to monitor for other pests and signs of their damage to integrate mating disruption successfully into the program. We also demonstrated installation of mating disruption twist ties.

Early June workshops were on an individual basis with growers who wanted to take the time to monitor for infestation on their own farms. We evaluated control of the first generation in early July by examining shoots in peaches and apples.

The goal is to develop a fact sheet in cooperation with Cornell faculty and IPM coordinator to assist growers and consultants in implementation of mating disruption for OFM control to be finalized in 2004.

Objective 2: Increase the efficiency and publicity of the OFM/CM trapping network.
A total of 150 traps were installed across the region: 2 Pherocon IIB traps per block for OFM, CM, and one for LAW. Traps were issued to growers and consultants to monitor flight of OFM in apples and peaches, and CM and LAW in apples. Traps were to be checked by growers/consultants once per week and by summer technician once per week to get the best count of OFM and CM flight in non-disrupted areas. Counts were gathered and summarized by Lake Ontario Fruit Program-CCE to incorporate into Fruit Notes, emails, and Fruit FAX, all available to growers, consultants, distributor field reps, and faculty. These counts assisted growers to properly time mating disruption and insecticide applications and assisted in validating the PSU degree-day model for OFM under development.

The orchards were identified by county and farm number: "O" for Orleans, "M" for Monroe, "N" for Niagara, and "W" for Wayne Co. The data was graphed using total moths caught per trap per season, for each species. And the trap catch data per week for each farm was graphed to detect peak flight of each generation, with theoretical DD based spray dates, and actual spray dates. These data will be reviewed with cooperating growers through the winter months to asit in planning for 2004 controls.

Objective 3: Project Evaluation
The success of the workshop and trapline project was evaluated on a small scale by control results of OFM, especially in grower orchards where fruit was rejected due to OFM in 2002. Measurements of success include percent fruit infestation at harvest and shoot infestation in orchards under mating disruption compared to chemical programs in sample blocks on growers' orchards. Grower interviews in January will document remarks of cooperator satisfaction with the program. Results will be used to identify pitfalls and develop the fact sheet for future implementation of mating disruption.

Spray records were collected to examine use patterns of classes of insecticides in peaches, apples and pears. Costs of OFM control inputs for each system will be compared for a final report in February-March, 2004, so growers can plan strategies for 2004.

The expansion of the monitoring network for OFM could impact on 28,000 acres of apples and pears in the region. As long as the processing apple industry uses a standard of 1 worm found in inspection, this project has great potential to impact on fruit quality and profitability. The number of truckloads rejected from processors in 2003 at locations where rejections occurred in 2002 will be an overall measure of success in our efforts.

10. Results and Discussion:

Objective 1. Worm Management Workshop
Growers from 35 farms, and 13 consultants from western New York attended the March workshop. They learned how to identify the distinguishing characteristics of OFM/CM/LAW. They learned about the differences in biology and signs of infestation. They learned about how to monitor for these pests using pheromone traps, and looking for the signs of infestation in shoots and fruit. They learned about how to use mating disruption pheromones for control of OFM and to determine if mating disruption was an appropriate control strategy based on population level, size and shape of orchard, density of tree canopy, and evaluating the orchard surroundings. They also learned about how to use degree day models to better time insecticide applications when they are necessary, and how effective the new and old insecticides registered in New York are for controlling internal lep pests. Presentations and fact sheets were included a workbook for attendees.

Reference materials used for this workshop were from L. A. Hull, et. al., from PSU, (unpublished data) and other researchers from Michigan and Ontario, Canada. Starting in January with the LOF Winter Fruit Schools, we started to raise awareness of some research about the biology of the OFM, CM and LAW, and successes in controlling these pests with mating disruption, and old and new insecticides. L. Hull gave a comprehensive presentation of research findings from his research team over the past 4 years. We used some of this research as a foundation for the workshop.

Approximately 40 growers attended the April Workshops where we demonstrated the installation of pheromone traps, discussed the best location of traps, and distributed colored fact sheet highlighting distinguishing physical characteristics of adult moths, larvae, and signs of infestation. Over 100 growers and 10 consultants attended the late May workshop where they had the opportunity to confirm their ability to identify adult OFM, CM, And LAW, next to the many imposters that are also caught in the traps. A final field opportunity was presented at the Lake Ontario Summer Fruit Tour in Wayne Co. where samples of larvae, adult moths, and infested shoots and fruit were available for growers, and consultants to become familiar with these pests. A special workshop was arranged with a consultant in WNY to train 5 field scouts to identify the signs of infestation by internal lep pests and learn the importance of identifying characteristics of larvae and adults. Identification is the first step critical step to choosing a management strategy.

A survey will be sent to those who attended the March Workshop to identify the method of control for internal lep pests they adopted for 2003 and rate the results, and plan for 2004. A larger survey will be conducted in January to determine the status of the internal lep problem and what strategies growers used to control them in 2003. This data will be shared with the Extension Entomologists to plan future educational and research needs.

Objective 2. Increase the efficiency and publicity of the OFM/CM trapping network.

Traps were set in a total of 21 farms in late April. Initially, growers were very diligent about checking traps and calling or emailing the data. But as the season progressed, we found that the growers were not able to dedicate specific days since they were also the ones who had to plan for other activities based on the weather. By mid-season, the technician was mainly responsible for checking and cleaning traps weekly, and replacing lures and trap bottoms on a regular schedule. In general, growers who had already delegated the scouting and pest monitoring activities to a consultant or fieldman were least likely to help in trap checking.

Those who did not have regular visits from a consultant or fieldman were willing to continue the effort at monitoring for these internal pests and expressed gratitude for the educational efforts through Cornell Cooperative Extension and IPM.

The first conclusion drawn from this project is that there is a lot of variability in pressure from each of the internal lepidopteran pest species from one farm to another. This is shown in Figures 1-3. Figure 1 shows that the total number of OFM moths trapped per block for the entire season ranged from 17-403, with an average of 170 moths per trap per season. Figure 2 shows that CM in general is not a major issue for the western New York apple industry except for a few high pressure locations. The total CM moths caught per trap per season ranged from less than 5 – 167, with an average of 38 moths per trap per season. Figure 3 shows a third pest, lesser appleworm, is also a factor in the internal lep complex. Lesser appleworm trap catch ranged from 14-117, with an average of 47 moths per trap per season. Comparing the block labels on the x-axes, this series of charts shows that individual orchards differ in the predominant pest species. For example, "O5" had the highest number of OFM, very few CM, and moderate levels of LAW. "O2" had the highest CM trap catch, one of the lowest OFM trap catches, and moderate levels of LAW. "W9" had very low populations of all 3 lep species. "N1b" had high populations of all three species. Therefore, it is critical for growers to survey the population of internal lep pests on their farms to determine the appropriate control strategies.

The variability in populations of internal lep species can only be detected with the installation and maintenance of traps for each species on the farm. The questions still remain: How many traps per farm or per block are necessary, and practical to obtain the necessary information? And where should the traps be hung, on the edge or inside the orchard?

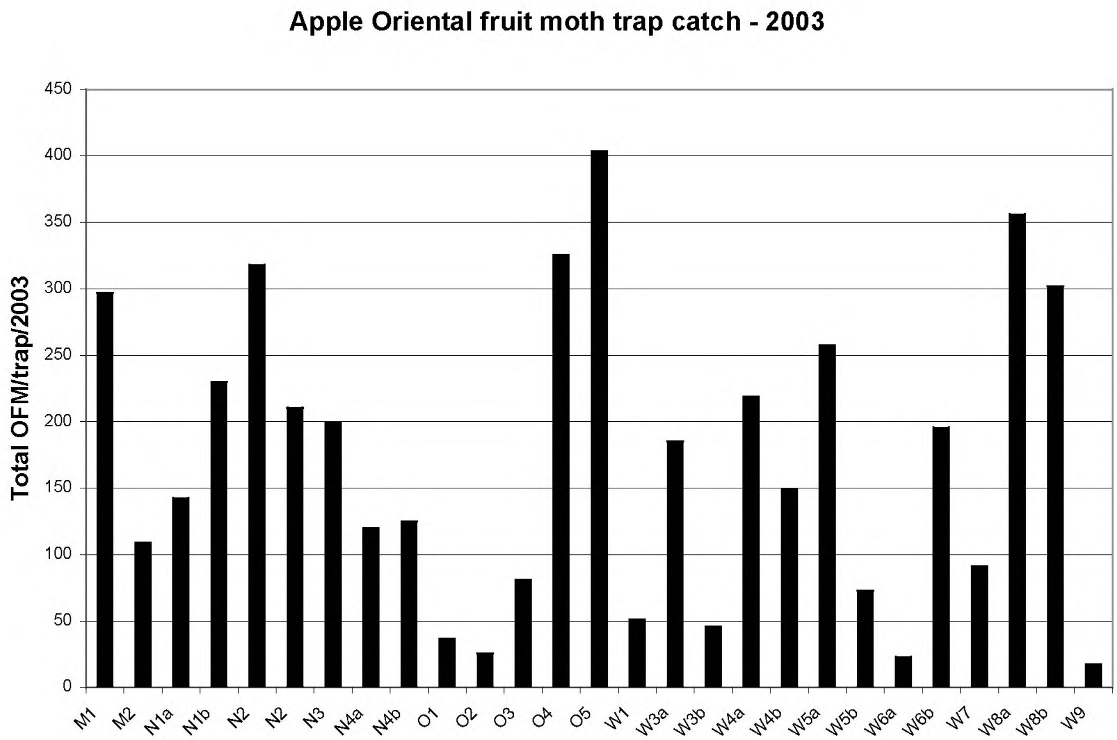
How many traps? Of 14 farms analyzed, 6 farms with 2 OFM traps showed one trap above a suggested threshold (8-10 moths per trap per week) and one below threshold for at least one of the peak flights in the season. An example of this is shown in Figure 5. Since wind direction and source of infestation outside of the orchard will vary, at least 2 traps would give a better picture of the population.

Figure 6 shows how trap counts will differ between adjacent farms. This can depend on spray schedules and insecticides used. This also emphasizes the importance of monitoring each farm. The last chart in Figure 6 demonstrates peak flight timing, used in timing insecticide application, may differ from one trap location to another on the same farm. So regional spray programs may not be accurate enough.

Figure 7 shows the differences in one farm between the OFM population in peaches (POFM1 and POFM2) and that in an apple block (OFM1 and OFM2) on the same farm. According to the PSU research, (unpublished data), OFM have a preference for peach shoots during the shoot growth phase and have a different rate of larval development when feeding on apples vs. peaches. Therefore you cannot rely on trap count data from peaches to plan for apple sprays or visa versa.

Finally, it is important to know which pests are the primary target since the control timing for them differs. Although mating disruption for OFM will also disrupt LAW, the control timing for LAW using insecticides will be similar to codling moth timing, not OFM as shown in Figure 8. So if you have high populations of LAW in the area but not CM, there is in increased chance of fruit infestation with LAW. This reinforces the need to identify the worms that are found in fruit to ensure the proper control strategy is taken.

Figure 1.


Apple Oriental fruit moth trap catch - 2003
Total OFM/trap/2003
0
50
100
150
200
250
300
350
400
450
M1
M2
N1a
N1b
N2
N2
N3
N4a
N4b
O1
O2
O3
O4
O5
W1
W3a
W3b
W4a
W4b
W5a
W5b
W6a
W6b
W7
W8a
W8b
W9

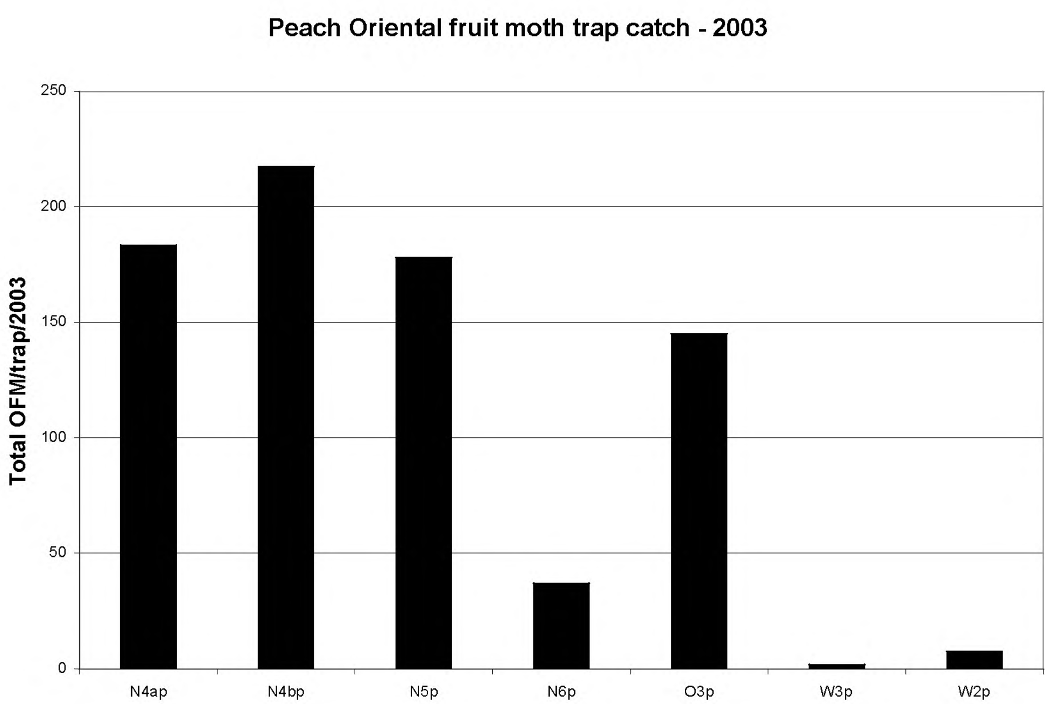

Peach Oriental fruit moth trap catch - 2003
Total OFM/trap/2003
0
50
100
150
200
250
N4ap
N4bp
N5p
N6p
O3p
W3p
W2p

Figure 2.

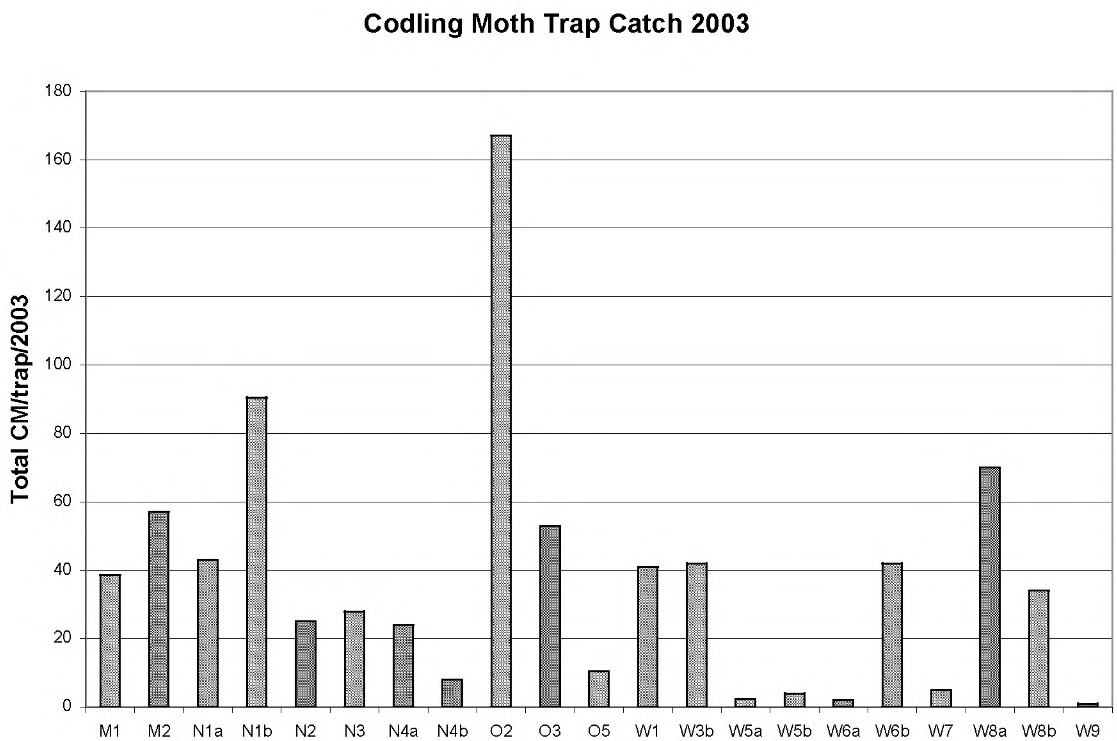


Figure 3.

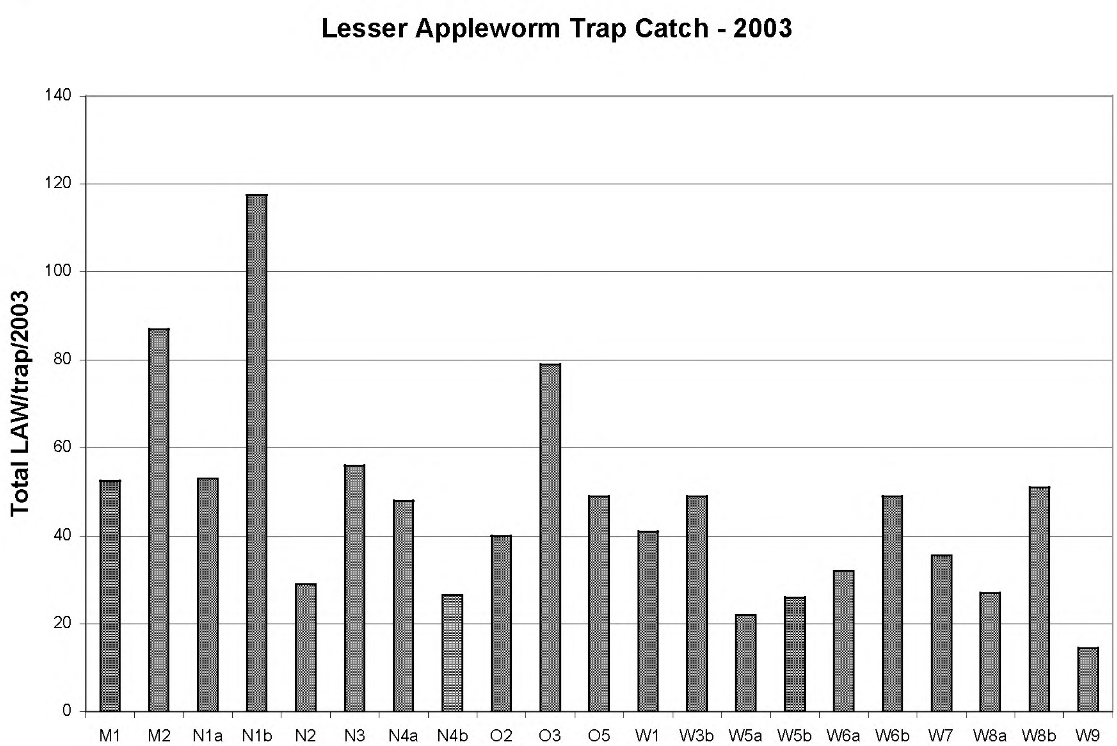


Figure 5.

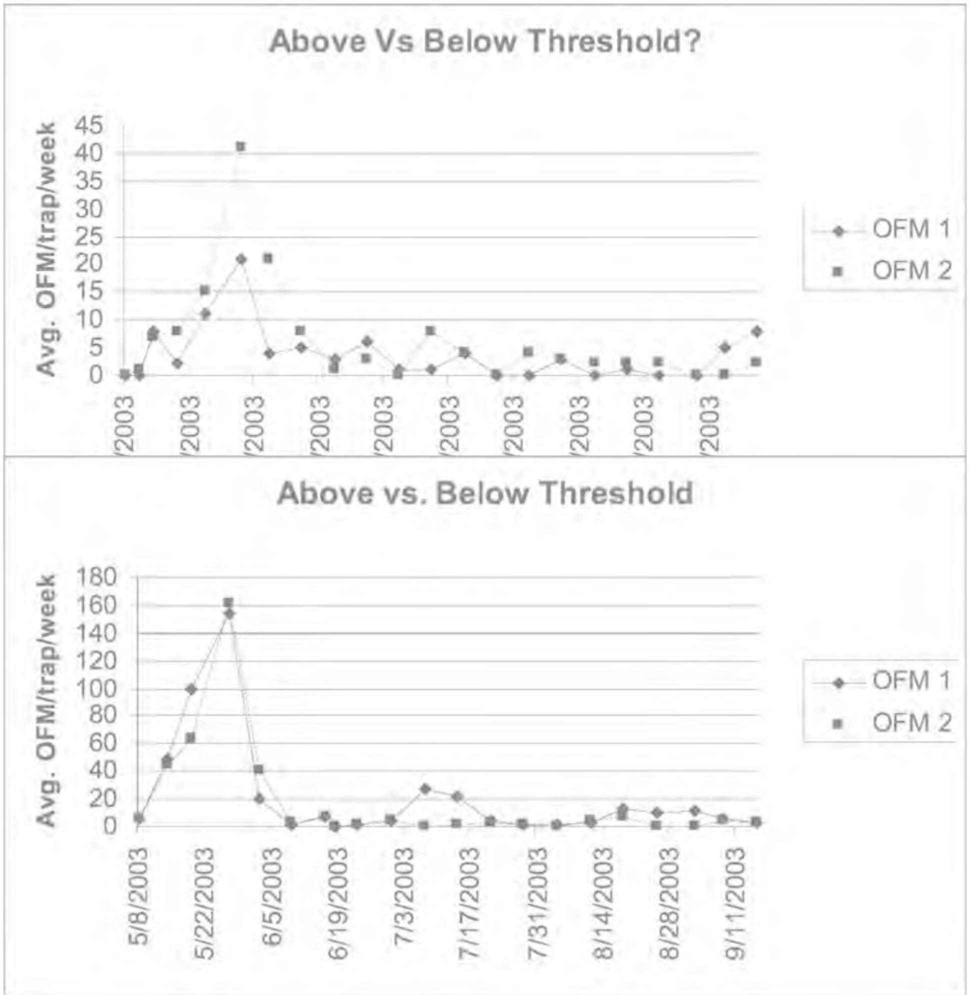
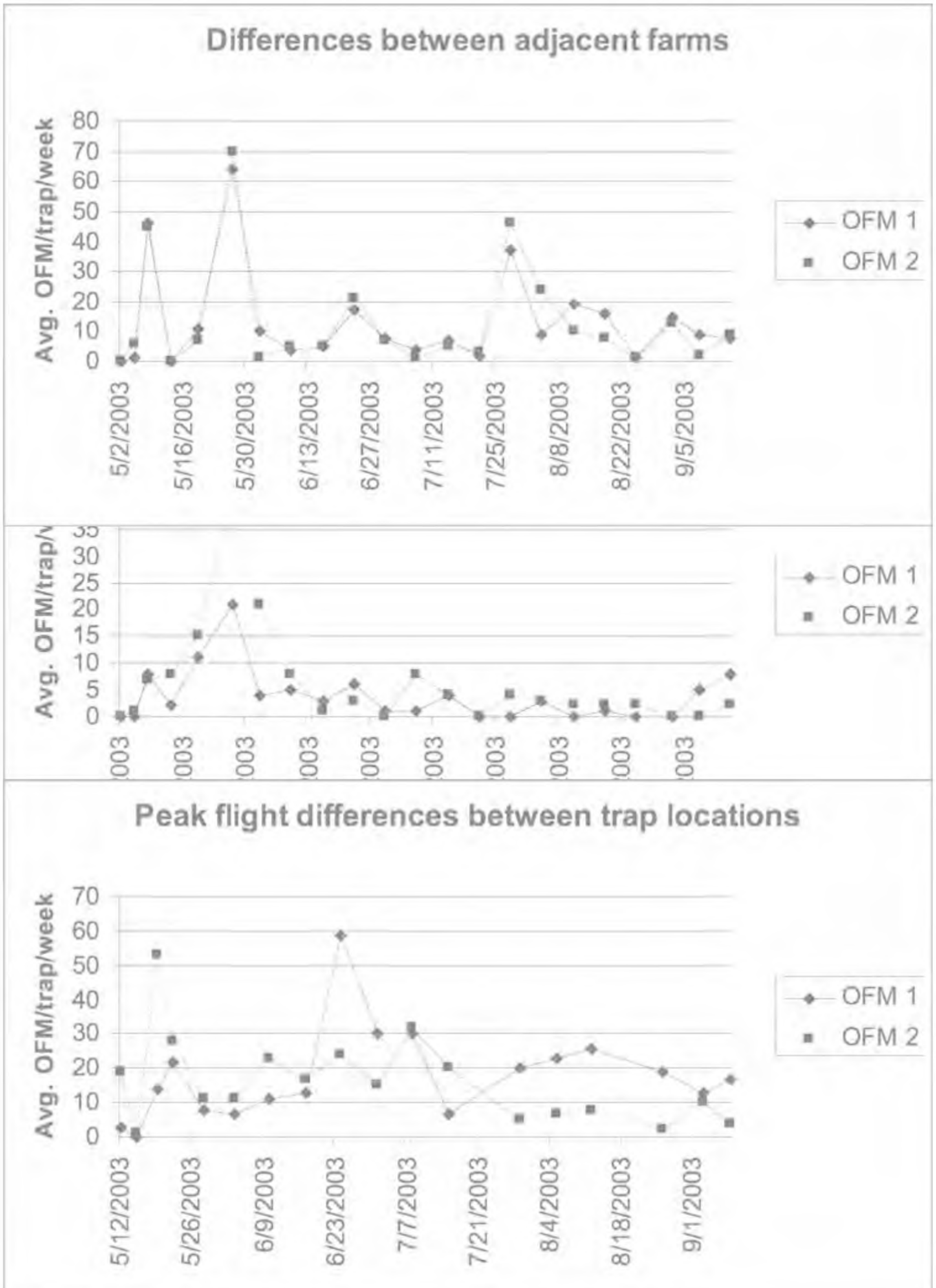

Above Vs Below Threshold?
Avg. OFM/trap/week
45
40
35
30
25
20
15
10
5
0
/2003
OFM 1
OFM 2
Above vs. Below Threshold
Avg. OFM/trap/week
180
160
140
120
100
80
60
40
20
0
5/8/2003
5/22/2003
6/5/2003
6/19/2003
7/3/2003
7/17/2003
7/31/2003
8/14/2003
8/28/2003
9/11/2003
OFM 1
OFM 2

Figure 6.



Differences between adjacent farms
Avg. OFM/trap/week
80
70
60
50
40
30
20
10
0
5/2/2003
5/16/2003
5/30/2003
6/13/2003
6/27/2003
7/11/2003
7/25/2003
8/8/2003
8/22/2003
9/5/2003
OFM 1
OFM 2
30
25
20
15
10
5
0
OFM 1
OFM 2
Peak flight differences between trap locations
Avg. OFM/trap/week
70
60
50
40
30
20
10
0
5/12/2003
5/26/2003
6/9/2003
6/23/2003
7/7/2003
7/21/2003
8/4/2003
8/18/2003
9/1/2003
OFM 1
OFM 2

Figure 7.

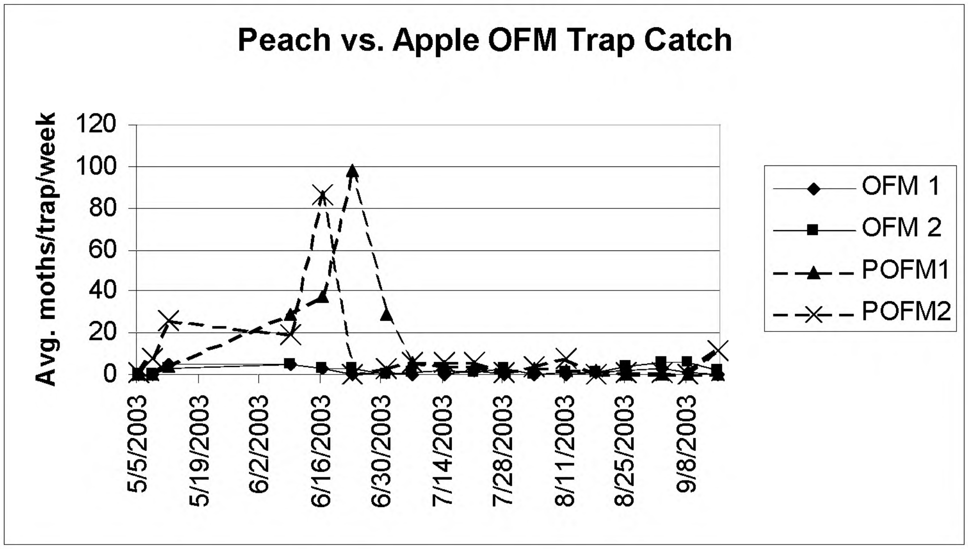
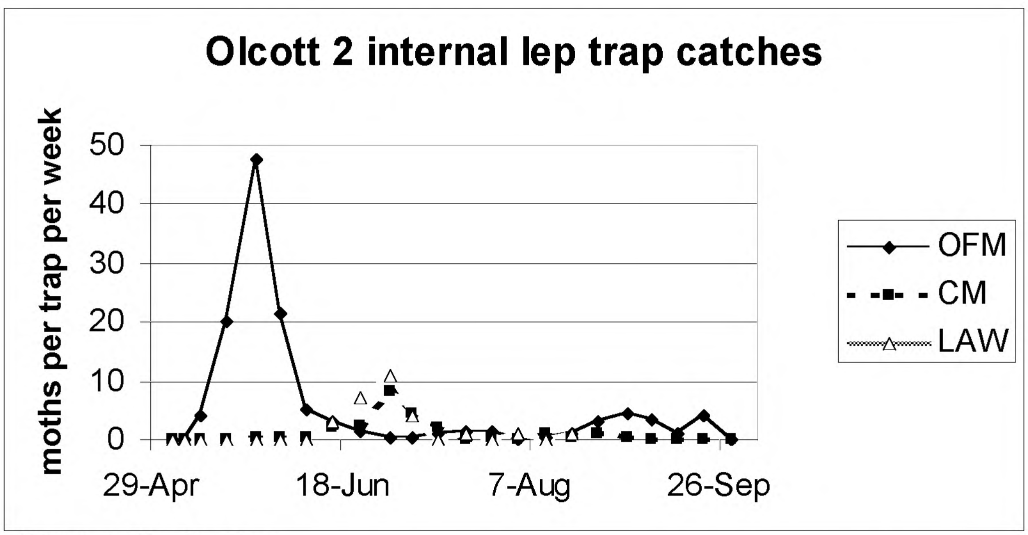


Figure 8.



Objective 3. Program Evaluation

Growers who attended the workshops and assisted in the trapline management, also allowed for harvest evaluations of fruit. Table 1 shows that of 20 apple blocks, harvest evaluations of 600 fruit per block showed 14 blocks with no internal lep damage. Block N1b3 had .5% damage next to a block under mating disruption. Block N1b2 was adjacent to N1b3, and was a combined insecticide and sprayable pheromone plot resulting in 1% internal lep damage. Block O2 was split into two treatments, Imidan (IM) and grower standard (GS) to run trials for control of a high population of CM, with very few OFM. O2-IM resulted in 1.7% internal lep damage, most of which was due to codling moth feeding. This plot was primarily treated with higher rates of Imidan according to trap catch results and the degree day model for CM control. Block O2-GS was treated with pyrethroids and some OP's resulting in 6.5% internal lep damage. This block may be a candidate for testing for OP resistance. Control in 2003 was a significant improvement in control over the >25% damage in 2002. Block W6c was an untreated section of W6b, which is not harvested commercially, but had 22% fruit damage showing the potential population pressure available for the commercial portion of the block. Block W6b had one load of apples rejected in 2002, but not in 2003.

Table 1. Fruit harvest evaluations for insect damage in 2003.

Apple Blocks	int lep	sting	AM	OBLR	OWOBLR	SJS/OSS	TPB
M1	0.0%	0.3%	0.0%	2.3%	0.0%	0.0%	0.0%
N4a	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
N4b	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.3%
N1b3	0.5%	0.9%	0.0%	0.5%	1.4%	0.9%	0.2%
O3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
O2-Im	1.7%	0.1%	0.0%	0.3%	0.0%	0.0%	0.1%
O2-GS	6.5%	0.8%	0.0%	0.2%	0.0%	0.0%	0.0%
O5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
W4 b	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%
W5a	0.0%	1.0%	0.0%	4.7%	1.0%	0.0%	0.0%
W5b	0.0%	0.3%	0.0%	2.0%	0.0%	0.0%	0.3%
W6a	0.0%	0.0%	0.0%	16.7%	0.3%	0.0%	0.0%
W6b	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%
W7	0.0%	0.0%	0.0%	0.0%	0.3%	1.7%	0.0%
M2	0.0%	1.0%	0.0%	3.0%	2.0%	0.0%	0.0%
W3a	0.0%	1.0%	0.0%	2.3%	0.3%	0.0%	0.0%
W3b	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	1.0%
Check Plot							
W6c	22.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Mating Disruption trials							
N7	1.3%	0.3%	0.0%	2.0%	1.7%	0.0%	0.3%
W4 a	14.0%	22.0%	0.0%	0.0%	0.0%	0.0%	0.0%
N1b2	1.0%	0.8%	0.7%	2.5%	1.2%	2.7%	0.0%

Spray records are not yet complete for all blocks, but preliminary data in Table 2 below show an increase in the number of applications of pyrethroids used in the system in most of the clean orchards. This was mainly due to economic issues with the registration of 2 new pyrethroid formulations in New York in the last couple years, with a cost of $10/acre per application. The new alternatives such as Avaunt cost $30/acre and are not effective against a broad spectrum of pests. Other growers were still trying to preserve mite predators and continued use of OP's instead of going back to pyrethroids.

Table 2. Crop protectant use in controlling lep pests in 2003.

Apple Blocks	Pyrethroids	OP	Carbamate	Avaunt	Bt.	MD
M1	5	3	0	0	2	0
N4a	5	1	0	0	0	0
N4b	5	1	0	0	0	0
Nb3	2	6	0	0	0	0
O3	6	5	0	0	0	0
O5	6	1	0	0	0	0
W4 b	3	4	0	0	1	0
W5a	4	1	0	0	2	0
W5b	4	1	0	0	2	0
W6a	7	2	1	0	1	0
W6b	7	2	1	0	1	0
W6c	0	0	0	0	0	0
N7	0	6.5	0	0	0	1
W4 a	0	3	0	1	1	3
Nb2	2	2	0	3	0	3
W7	na	na	na	na	na	na
M2	na	na	na	na	na	na
W3a	na	na	na	na	na	na
W3b	na	na	na	na	na	na

Overall, the internal lep management programs across the region were successful at minimizing internal lep damage. A processor who reported 113 loads rejected from 48 growers in 2002, had only 13 loads rejected from 11 growers in 2003. Only one load from one of the 11 growers with worms detected in fruit attended the workshop; the others with worms detected in fruit did not attend the spring workshop.

This complex of internal fruit feeders is driving pest management programs, and economics is driving the return to pyrethroids. The internal leps have challenged our biological mite management programs, but 2003 was not a serious mite year with the more than average rainfall. In some regions of the world, the use of pyrethroids has allowed for predator mites to become resistant to pyrethroids and continue to contribute to mite management programs. This is not known to be the case currently in New York. In spite of the economics, it is certain that the season long use of pyrethroids is not sustainable due to potential for resistance in the lep pest populations and an increase in wooly apple aphid populations. It is still critical to use alternative materials, and mating disruption where it fits to prevent resistance development and try to hold the populations to low levels. We will continue to encourage the use of monitoring, using mating disruption where feasible, and alternative insecticides.

Future Work:

- ✓ Survey industry and interview trapline cooperators
- ✓ Calculate spray costs for insect management using insecticides and mating disruption.
- ✓ Develop fact sheet for implementation of mating disruption.
- ✓ Survey predator mites for resistance to pyrethroids.
- ✓ Continue work with alternative materials such as granulosis virus for codling moth, and other new materials as they are registered in New York.