FINAL REPORT
WTFRC Project #AE-01-222 **WSU Project #13C-3643-4093**

Project title:	Developing behavioral-based control tactics for codling moth, leafrollers and lacanobia fruitworm.
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Objectives:

1. Evaluate sprayable pheromone systems for behavioral control of codling moth.
2. Evaluate fiber pheromone formulations for behavioral control and attract & kill possibilities for leafrollers and codling moth.
3. Evaluate an attract & kill technology LastCall formulation for leafrollers in large field trials for efficacy and rate effect.
4. Develop a bait & kill system for control of lacanobia fruitworm and assess the impact on other noctuids in orchards. **(Not addressed due to lack of pest importance)**
5. Evaluate the potential of a new flake pheromone formulation for CM control.

Significant findings:

2002

1. Sprayable pheromone for CM control did not perform well in orchards with moderate to high pressure. This technology may only be applicable to very low-pressure orchards where it could be incorporated as part of a spray management program.
2. Sprayable pheromone as a control for leafrollers was not encouraging but could provide some suppression if incorporated into a regular spray management program for other activities.
3. The Scentry fiber pheromone showed promise in preliminary studies for longevity of attraction, retention on foliage and suppression of moth activity when applied with a prototype ground applicator.
4. An attracticide formulation for OBLR and PLR was developed and optimized. Field studies indicate sufficient longevity, and preliminary small plot field trials were promising enough to propose large plot trials in 2003.

2003

1. Suterra CM-F sprayable pheromone contributed to suppression of codling moth (CM) activity when combined with supplemental insecticides in low-pressure orchards. Higher rates of CM-F sprayable pheromone performed as well in low-pressure orchards when compared with hand-applied dispensers at half rates. CM-F sprayable does not perform as well as the full rate of hand-applied dispensers in moderate- to high-pressure orchards.

2. The Scentry fiber pheromone showed promise in large field trials for suppression of CM and leafroller adult flight activity when applied with the modified ground applicator. An “attract & kill” product, when combining fibers with permethrin, looked promising in field trials this year, particularly for OBLR.
3. The IPM Technologies’ OBLR and PLR LastCall attract & kill formulation reduced moth activity significantly in large field studies in both generations. The reduction of adult moth activity could not be directly correlated with larval populations.
4. The female OBLR traps used in the Scentry fiber and LastCall trials in the first generation showed a low percentage of female recovery, either due to predation or escape. The modification in the second generation allowed for a high recovery rate of females, but percentage of females mated and males captured was very low overall. A system for assessing female leafroller mating status remains an issue.

2004

1. The Scentry fibers continue to look promising for codling moth and OBLR when applied with the modified ground applicator to large field trials. The 100-gram rate of fibers seems to be comparable to Isomate C-Plus hand-applied at 200 dispensers per acre in low-pressure situations. Air applications of fibers made by helicopter also looked promising, but efficiency of the application is in question because the “pods” used under the helicopter tend to swing, allowing for variable consistency in distribution of fibers. Fruit injury at harvest in the majority of blocks was minimal. There was no difference between treatment rates but significant difference between treatments and untreated (no pheromone) control blocks. All codling moth and leafroller sites had at least one cover spray per generation targeted at the respective key pest.
2. Hercon CM Disrupt “flake” pheromone technology remained attractive through the duration of a CM generation. Retention on foliage was good. The application systems tested provided a good distribution of flakes in trees. In small plots and single-tree experiments the Hercon CM Disrupt flakes significantly reduced male moths’ ability to locate females or female mimics in traps. The Flake formulation performed well in second generation compared to hand-applied and untreated control. The modified leaf blower application has the potential to be more efficient and easier for commercial applications by the grower. More experience with this technology is needed.
3. Hercon CM Disrupt “fringe” hand-applied dispensers did not perform as well as Isomate C-Plus or Isomate CTT in the trials that were conducted. In low-pressure situations the Hercon Disrupt dispensers were unable to effectively reduce pheromone trap catch compared to Isomate hand-applied treatments, even at “half rates.”
4. IPM Technologies, Inc. LastCall OBLR formulation continued to perform well at half or full rates. There was no significant difference between treatments, but all treatments performed better than the untreated control. The PLR formulation was used in a low-pressure situation and did reduce trap catch compared to the control but was not significant. Application of the product may be the only restricting aspect of its commercial use in the future.

Methods:

See details of methods in previous years proposals and progress reports.

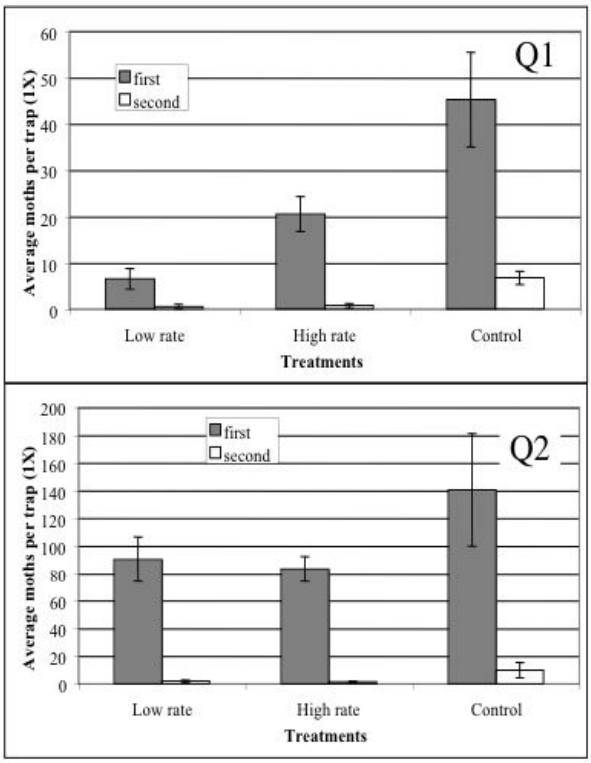
Evaluations of different pheromone formulations (sprayable, hand-applied, fibers, attract & kill) were conducted in commercial orchards with cooperating growers. Treatments were applied to large plots (2 to 10 acres each) replicated (three times) at different locations. Plots were monitored for moth activity with pheromone and non-pheromone lures one or two times per week. Sampling foliage or fruit from each plot at appropriate times of the year was used to assess pest density or fruit injury.

The duration and retention of new pheromone delivery technologies (fibers, flakes, attract-and-kill) was determined through replicated studies. Treatments were applied to different tree parts and retention followed over time to determine retention times on surfaces. Fibers, flakes or attract-and-kill technologies were placed in pheromone traps to determine their attractancy over time. Moth captures in traps were recorded and compared to a standard attractant source (lure).

Results and discussion:

CM sprayable pheromones:
Sprayable pheromone formulations (Suterra and 3M) were evaluated in 2002 and 2003 in replicated large plots in commercial orchards. The Suterra formulation provided some suppression of CM using 5 applications per season similar to a half-rate of Isomate C-Plus. Sprayable formulations in general are not robust pheromone technologies for CM management when applied through a speed sprayer or highly concentrated specialized device.

CM Scentry fibers - ground application:
Codling moth **-** Treatments of 33 and 66 grams of Scentry codling moth (CM) fibers were mixed with BioTac 25/100 weight (50:50) for first generation application to three sites in Quincy (Q1 and Q2) and Malaga areas. The targeted application rate was for 50 and 100 grams of fibers per acre, but product mislabeling caused reduced rates in first generation. Each treatment was 5 acres in size, with either hand-applied dispensers or untreated (zero mating disruption) as comparison blocks. The first generation application was targeted for 14 days after petal fall with the cooperator/grower applying Intrepid at 12 oz/acre 7 days after petal fall. This timing was to accomplish two things: 1) optimal foliage/surface area for fibers to adhere to; 2) Intrepid application of 12 oz/acre would allow efficacy of codling moth eggs already laid and any future eggs deposited on top of Intrepid. The two Quincy trial blocks were moderate to high pressure with a total trap reduction of 55-86% compared to the untreated controls. The other blocks in Malaga had very low pressure and showed no difference in total trap catch between treated and hand-applied dispenser blocks.



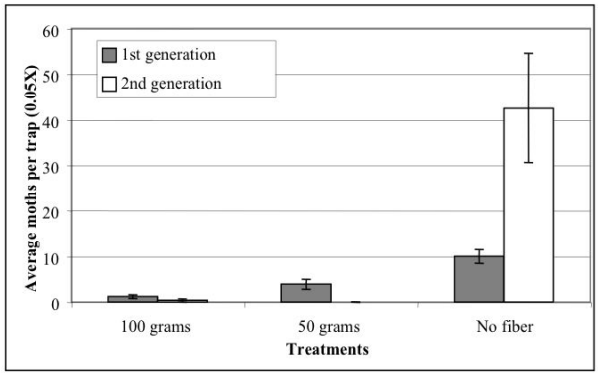
At the start of the second flight, application of fibers increased to 50 and 100 grams mixed with BioTac 100/300 weight (50:50) at the Quincy sites and 100 grams at Malaga. Results in the second generation at the Quincy sites showed a statistically significant reduction in trap catch ranging from 82-93% compared to the untreated comparison blocks. The Malaga sites showed no difference between treatments. There was no difference in mating status in fiber treated or untreated blocks in either locations. Fruit injury remained very low at all sites in both first and second generations, with the Quincy sites averaging <1% damage and Malaga showed a reduction in damage compared to the hand-applied blocks but it was not significant.

CM Scentry fibers - air application:

Codling moth **-** Two sites in Chelan and Malaga received commercial applications of Scentry CM fibers by helicopter at the discretion of the growers and their consultants. Monitoring was done to gain more experience with methods of application that are available to the grower. There was no untreated block to use as comparison at either site. At the Chelan site, average moth catch per trap was 1.7, and Malaga catch ranged from 6.6 to 36.5 per trap. Traps were placed at a rate of 1 trap/lure per acre. Fruit damage at the end of first generation was 0% at Chelan and ranged from 0%-3.8% at the Malaga site.

In the second generation the Chelan site was discontinued because the grower and consultant did not treat again with fibers due to very low pressure. A new site with high pressure was added at Bray's Landing and had an untreated control for comparison. In the fiber treatment, 1x lure baited traps averaged 34 moths per trap compared to the untreated control at 37 moths per trap. Fruit injury was significant with 7.7% and 9.3% in the fiber treated area and 4.4% and 2.5% in the untreated control area.

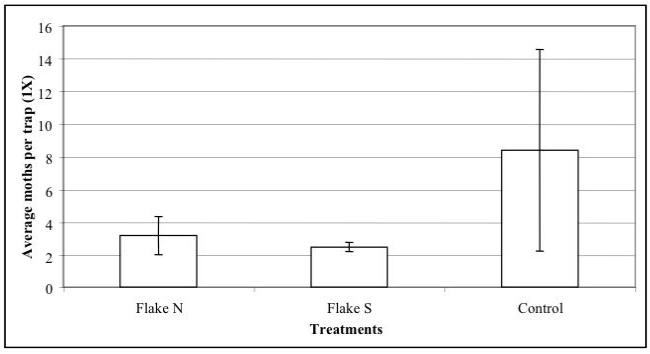
OBLR Scentry fibers:



Scentry OBLR fibers were applied at 50 and 100 grams mixed with BioTac 25/100 weight first generation and 100/300 weight in second generation to three locations, Desert Aire (figure shown), Quincy and Monse. Both treatments showed a significant reduction in trap catch at Desert Aire in both generations compared to the untreated with reductions of 60-80% in first generation and 99-100% in second generation. Due to application problems the Quincy site received only 25 and 50 grams respectively in the first generation. Even at this reduced rate there was a reduction of 83-100% in trap catch compared to the untreated control. In the second generation the full rate was achieved and had near trap shut-down at reductions of 88-97%. The Monse site was very low pressure with no difference in trap catch first generation but in the second generation trap catch was significantly different with 85% reduction in treated blocks compared to the untreated comparison.

This year the live female traps that were developed by Dr. Vince Jones in 2002 were replaced with acetic acid food-based baited traps developed by Dr. Peter Landolt. These traps were used to assess mating status in all OBLR trials in both generations.

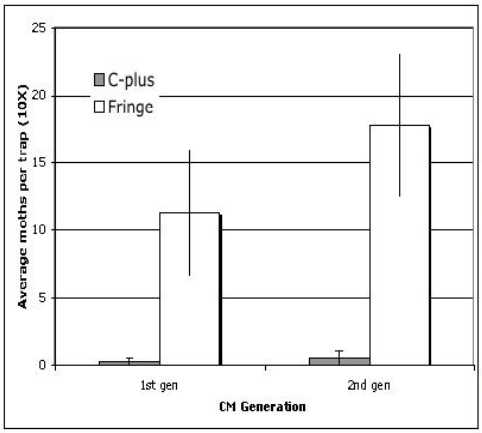
Hercon CM Disrupt "flakes":



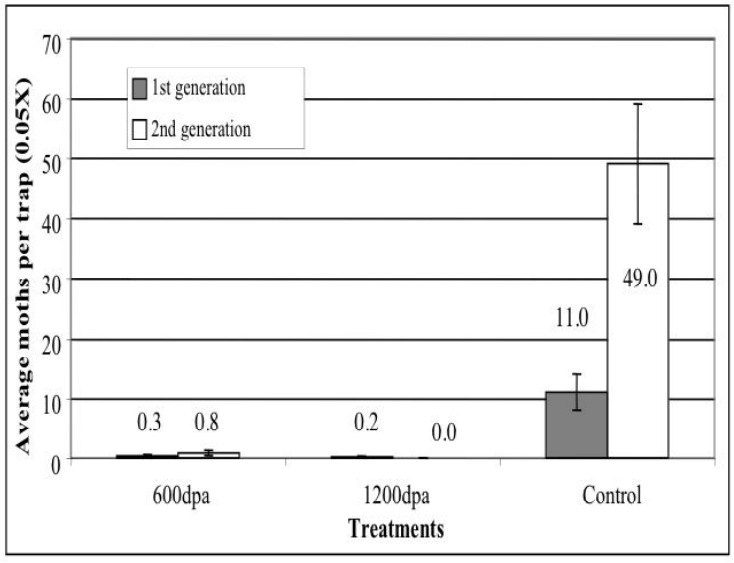
Codling moth **-** This was one large site located in Quincy that we monitored in the second generation only. Cooperating with the Hercon technical consultant and commercial grower, this site was set up to compare the new technologies of pheromone "flakes" with the new hand-applied Hercon CM Disrupt "fringe" and an untreated control. Reductions in pheromone trap catch in the "flake" treatments were 43-70% compared to the untreated control. There was no difference in trap catch between the hand-applied and the untreated

control. The flake treatments mating status was 43-75% mated females compared to hand-applied at 88% mated and untreated control at 75%. Fruit injury assessment prior to harvest showed 88-95% reduction in the "flake" treatments and 17% reduction in the hand-applied compared to the untreated control at 10.8%.

Hercon CM Disrupt "fringe" hand-applied dispensers vs. Isomate C-Plus/CTT: Two 10-acre sites in the Wenatchee valley were treated with Hercon CM Disrupt "fringe" hand-applied dispensers at 120 dispensers/acre compared with either Isomate C-Plus at 200 dispensers per acre or Isomate CTT at 200 dispensers/acre. The Isomate C-Plus and Isomate CTT performed better in both generations with 10x red septum pheromone traps showing 67-100% reduction compared to the Hercon hand-applied technology. DA lure trap catch in first generation was very low but in second generation increased, and mating status from all hand-applied treatments ranged from 80-100% mated. Fruit injury was very low in all treatments with no significant difference.

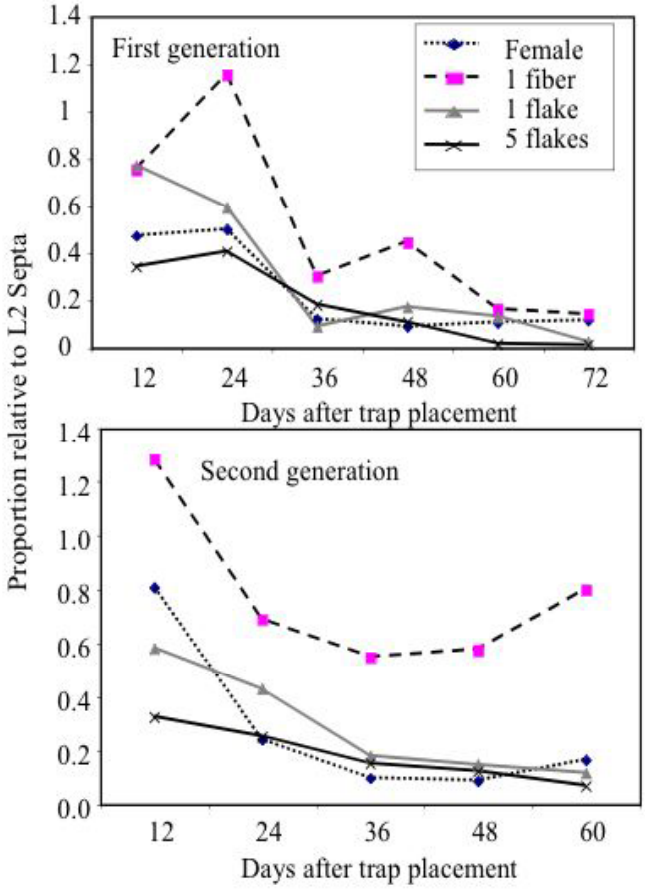


OBLR LastCall: Attract & kill formulations for OBLR were used in large 5-acre plots to determine efficacy on obliquebanded leafroller. Rates of 600 and 1200 drops per acre were used. Sites were located in Quincy (figure shown) and Pateros. There was no effect on trap catch between rates of LastCall with 97-100% reduction at all sites compared to the control. Two of the three sites had supplemental control for leafroller.

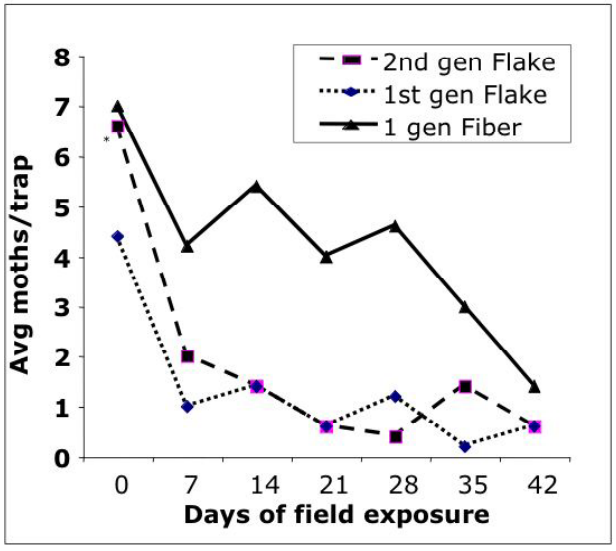


PLR LastCall: This was a site just south of Wenatchee on Stemilt Hill, which received two supplemental sprays for control. The site received only one treatment of 1200 drops per acre compared to an untreated control. Pressure was very low in both generations with 90-100% reduction in 0.1x baited pheromone traps compared to the control.

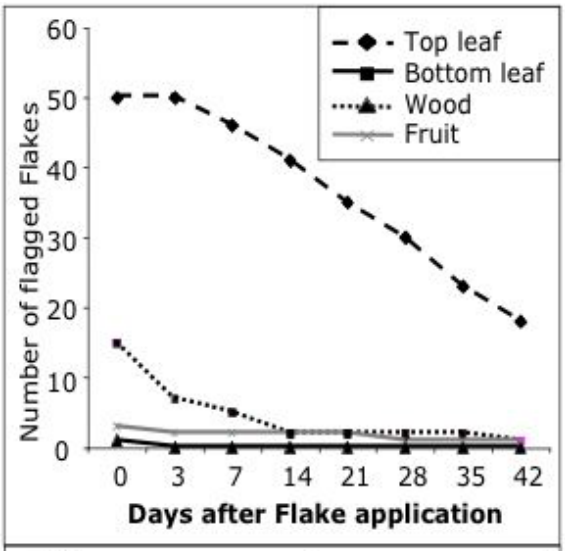
NoMate CM fiber and Disrupt CM flake attractiveness: NoMate CM fibers and Disrupt CM flakes were attractive to CM males over the entire first and second generation flights (figure to right). The L2 lure was the most attractive lure used during both generations. During the first generation test, the fiber lure attracted as many moths as the L2 lure through 24 days but was significantly less attractive for the rest of the flight period. The flake lure attracted as many CM males as the fiber lure through 36 days, but appeared to lose relative attractiveness for the rest of flight. The flake lure was close in attractiveness to CM males as a virgin female lure. During the second flight, both the fiber and flake lures were statistically equivalent to the L2 lure through 24 days. From day 24-60 the fiber lure maintained its relative attractiveness to the L2 lure, attracting 60-80% as many CM males. The fiber lure was statistically equivalent to the L2 lure after each rotation, except 48 days. The fiber lure attracted more CM males than the flake lure at 48 and 60 days. Again, the flake lure appeared to be as attractive as a CM female over the entire flight.

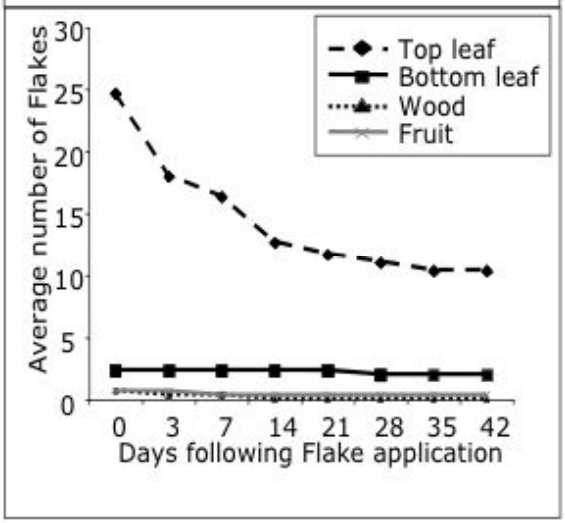


Effect of field-aged exposure on NoMate CM fibers and Disrupt CM flakes on attractiveness and longevity: The effect of field-aging Disrupt CM flakes resulted in a decrease in relative attractiveness after 7 days of exposure (figure at right). However, in only during the second generation test was the decrease in attractiveness statistically significant (F ratio 2.86, df 6, Prob>F 0.03). These data suggest that additional exposure from 7-42 days did not affect relative attractiveness during the first or second generation. NoMate CM fibers appeared to lose relative attractiveness later in the first generation; however, at no time was the loss in attractiveness relative to day 0 fibers statistically significant. Fibers attracted numerically more CM males over the entire first generation than the flakes; however, only at 7 days (*t* 2.67, df 8, Prob>*t* 0.03) and 28 days (*t* 2.29, df 8, Prob>*t* 0.05) was this difference statistically significant.

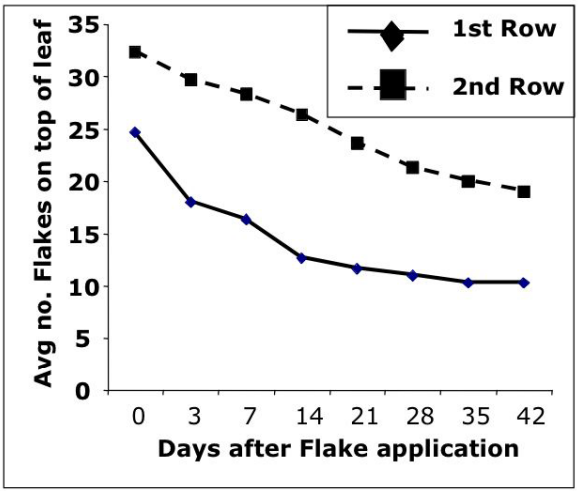


Disrupt CM flake (photo) application efficiency and retention: Statistical analysis was difficult with the hydroseed applicator trial due to the unreplicated experimental design, but clear trends were still apparent in this study. The recommended rate of Gelva was 48 fl oz/5 gal, and at this rate the hydroseed applicator was able to stick many more Disrupt CM flakes on the tops of the leaves than on the bottom of leaves, wood or fruit (right top). It was apparent that this rate of Gelva was insufficient to stick flakes on these other surfaces. Flake retention on the tops of leaves was a fairly linear decline with approximately 40% of the flakes remaining after 42 days. The adhesive study indicated that 48 fl oz rate of Gelva may have outperformed the 32 fl oz rate with more flakes being retained at 3 and 7 days. From that point on, the loss rate was slightly more in the 48 fl oz treatment, and at 42 days both treatments had the same number of flakes remaining on the upper surface of the leaves. It is clear that adding Guar Gum to Gelva significantly increased flake adhesion to the tops of leaves (72% after 42 days) but also to the bottom of leaves (48% at 42 days), wood (44% at 42 days) and fruit (28% at 42 days). However, at the high volume used in the hydroseeder applications, the addition of Guar Gum resulted in stickiness on the trees and fruit that probably would not be horticulturally acceptable.

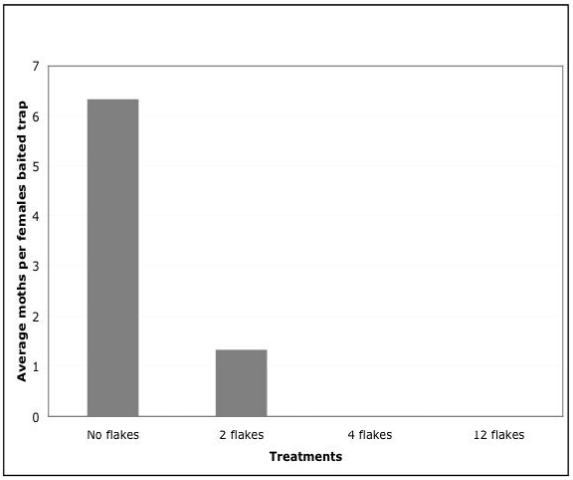




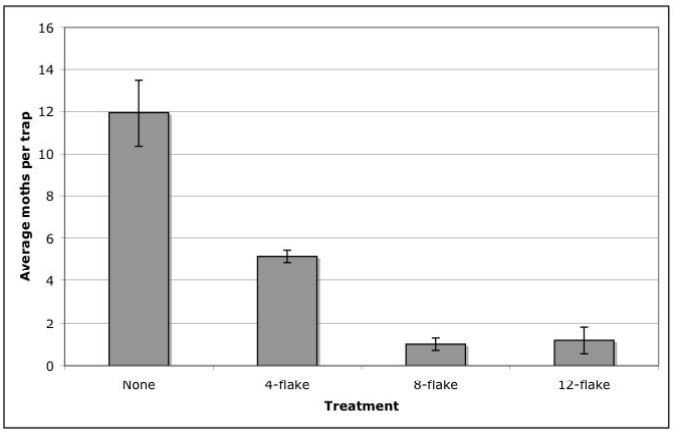
The blower applicator was also more efficient at applying flakes to the upper surface of leaves, as very few were stuck on the bottom of leaves, wood or fruit (right bottom). An average of 25 flakes per tree were found within 24 hr of application. Flake retention declined linearly through 14 days, but from that point on very few flakes were lost and after 42 days 40% remained. Although Guar Gum was necessary to adhere flakes using the blower applicator, the blower operated at a much lower volume and the same sticky residue on fruit and leaves was not noted. Interestingly, more flakes were deposited on trees in the second row from the blower application than on the first row adjacent to the application (figure on next page). The difference in flake deposition between the rows was not statistically significant, but these data suggest that the blower was operating efficiently over two rows. Blower applications traveling at 8 mph should be able to efficiently cover a large acreage in a relatively short time.



Point source density experiments: In Experiment #1 an average of 6.3 moths were captured in the trees without flakes. Where there were 2 flakes per tree an average of 1.3 moths were captured. No moths were captured in female baited traps in trees with 4 or 12 flakes per tree (see bar graph below).



In Experiment #2 an average of 6.0 moths were captured in the 0-flake (control) treatment. We had another control in trees in the same orchard but at a longer distance from the treated trees (see bar graph below). In this control an average of 8.6 moths were captured, slightly more than the treatment control (no flakes) indicating that there may have been some interference due to proximity of the flake treatments. All of the flake treatments significantly reduced moth capture in fiber-baited traps. We know that fibers used as lures are more attractive than virgin CM females. This is because they either release more pheromone or because they are always calling while females call for only a short period each night. There seemed to be little difference associated with the location of flakes, though when only 2 flakes were used and placed to the side of the trap vs. above and below fewer moths were captured. Could this indicate something about how competition between different sources occurs?



In Experiment #3, which was very similar to Experiment #1, an average of 11.9 moths were captured in the trees without flakes. Where there were 4 flakes per tree, an average of 5.1 moths were captured. The number of moths captured in trees with 8 or 12 flakes per tree was not different from each other but significantly less than the 4 flake treatment (figure at left).

In Experiment #4 an average of 2.0 moths were captured in the trees without flakes and monitored with the fiber-baited trap. The number of moths capture in the 2 flakes per tree treatment was only slightly lower (1.6 moths per trap) than the untreated control, but the 4 flake treatment had significantly lower catch, 0.8 moths per trap. When the L2 lure was used as a monitoring tool fewer moths were captured in all treatments but the same trend in moth capture was evident but not statistically different.

Budget:

Project title: Developing behavioral-based control tactics for codling moth, leafrollers and lacanobia fruitworm.
PI: Jay F. Brunner
Project duration: 2002-2004 (3 years)
Project total (3 years): $104,267

Year	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Total	37,280	32,365	34,622

Item	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Salaries[1] (0.5 Betsy Stutzman, formerly Valdez)	15,000	15,450	18,694
Benefits (30%)	4,500	4,635	5,608
Wages[1]	8,000	8,000	7,000
Benefits (16%)	1,280	1,280	1,120
Equipment[4]	5,000	0	0
Supplies[2]	1,000	1,000	700
Travel[3]	2,500	2,000	1,500
Miscellaneous	0	0	0
Total	37,280	32,365	34,622

[1] 50% of Associate in Research and temporary labor for summer activities.
[2] Pays for traps, lures, baited, gloves, vials, etc. Cell phone charges are allowed.
[3] One vehicle for 6 months plus fuel and maintenance.
[4] Fans, framing and materials to construct a field wind tunnel for behavioral studies and evaluation of mating disruption products.

Additional funding supporting this project in the amount of $40,000 per year was provided.