FINAL REPORT
WTFRC Project #AE-01-49 **WSU Project # 4093**

Project title: Evaluation of sprayable pheromone and attract & kill for codling moth and leafroller control

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Objectives:
Develop a pheromone-based management program for codling moth and leafrollers by:
1. determining if sprayable pheromone technology will provide control of codling moth and leafrollers in commercial orchards.
2. developing a leafroller attract & kill product for PLR and OBLR and determining if these will provide commercial level control of these pests.
3. determining if the efficacy of new hand-applied dispenser systems (Pacific Biocontrol) will provide suppression of codling moth and leafrollers equal to current technology.

Significant findings:
1999
- Early tests with a sprayable pheromone (3M) for leafrollers showed that the 40 g AI/acre rate was more effective than the 20 g AI/acre rate. One application per flight was not sufficient to reduce moth activity throughout the entire flight period. There was little difference between sprayable pheromone applications applied at a two-week versus a three-week interval. None of the sprayable pheromone treatments was as good as a hand-applied dispenser leafroller pheromone treatment.
- A long-term project was initiated comparing leafroller hand-applied pheromone dispensers (Pacific Biocontrol). In the first year the 250 mg dispenser (season long) suppressed moth activity slightly better than the 80 mg dispenser (90 day). There was indication that the pheromone treatments reduced leafroller larval densities, but results were not consistent at all sites.
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2000
- A second year of leafroller sprayable pheromone tests showed fair effect of treatments on moth activity in a three- or four-spray program. Where sufficient populations existed, there was a suppression of leafroller larval densities and fruit damage in the pheromone treatments.
- In a rate study comparing 5, 10, 20 and 40 g AI/acre of sprayable leafroller pheromone there was a significant direct relationship between rate and suppression of moth activity.
- Application method, airblast versus Proptec, did not make a difference in activity of the sprayable pheromone.
- A paraffin emulsion containing codling moth and leafroller pheromone (Gowan, Inc.) was tested in 2000. Treatments of 15, 30 and 60 g AI/acre showed a slight rate effect. The formulation shows some promise for development as a possible mating disruption product, but it needs more development.
- IPM Technologies' Last Call-OBLR at 600 and 1200 drops/acre suppressed moth captures in traps but did not affect the density of larvae in test plots.

2001

- Two formulations of sprayable codling moth pheromone were tested and showed varying degrees of promise as a technology for managing this pest. Additional large plot trials are required before it can be recommended for growers use.
- A third year trial with a sprayable leafroller pheromone formulation showed some promise as a technology for managing this pest. Trap shut-down is not as great as with hand-applied dispensers.
- Hand-applied leafroller dispensers were evaluated for the third year. The season-long dispenser or single-flight dispenser showed promise in reducing moth activity and in limiting leafroller densities. There was indication of reduction in mating frequency associated with the treatments and in reduction of larval densities.
- An attract & kill (A&K) formulation using the Last Call (IPM Technologies) base formulation and different concentrations of PLR or OBLR pheromone was evaluated. Attraction of moths to the A&K formulation was proportional to pheromone concentration. It appears that higher pheromone concentrations are required in the A&K formulation than currently are being used. Incorporation of permethrin in the A&K formulation did not reduce attraction of leafrollers to the sources.
- Aerial applications of Scentry's fiber pheromone formulation showed promise as a control of leafrollers based on reduction in trap captures throughout the entire first flight (50 days). This formulation has a promise to be developed as an attract & kill product for leafrollers and codling moth.
- Aerial applications of Scentry's fiber pheromone formulation showed some promise as a control of codling moth based on reduction in trap captures and damage at harvest. Additional research is needed on application technology, distribution of fibers and attraction of fibers to moths.
- The evaluation of five different hand-applied codling moth pheromone dispensers showed variable pheromone release behaviors when analyzed using three different methods. This information will be helpful in clarifying some confusing claims made of different dispenser systems by registrants.
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1999-2001 Summary

- **Sprayable leafroller pheromones** – Three years of studies, some at the same site show that this technology requires at least two applications per flight, probably at 20 g AI/acre. There is interest in this technology, and continued research is proposed working with newer formulations. It is likely that this technology will be integrated with soft pesticides for successful leafroller management.
- **Sprayable codling moth pheromones** – There appears to be promise in this technology as a CM control. Two companies are working on formulations. Continued research is proposed working with this technology.
- **Hand-applied leafroller pheromones** – These products have a strong effect on moth activity. There was also a reduction in mating and larval densities in pheromone treatments compared to conventional control programs. The season-long dispenser (250 mg) could be adapted to CM hand-applied dispenser programs because it could be placed at the same time as the CM dispensers and still last the entire season.
- An older pheromone delivery technology, Scentry fiber pheromone, shows promise as a codling moth and leafroller control. This technology was used in cotton to suppress the pink bollworm. It also has the potential to be developed as an attract & kill product. The advantage of this technology is that it can be applied by air. Additional research is proposed working with this technology.
- **Attract & kill** – A technology based on Last Call formulations shows that the leafroller pheromone is not released from the matrix as efficiently as the codling moth pheromone. At higher concentrations of pheromone in the formulation, attraction to the source increases. Additional development research is required to make this technology more efficient as an attract & kill approach for leafrollers.

Methods - 2001:
3M sprayable codling moth pheromone – Royal Slope: 3M sprayable CM pheromone (3M-CM) was applied to an unreplicated large block (6 acres) at the Royal Slope orchard at a rate of 10 g AI/acre in the first flight. The orchard was monitored with the standard 1X pheromone lures and Trécé DA kairomone lures in delta-type traps at one per acre. A two-acre untreated plot directly adjacent to the pheromone treated plot was monitored in a similar manner. The 3M-CM was applied on April 26. Damage after the first generation was rated by examining 30 fruits per tree from 30 trees in each two-acre section of the pheromone treated and untreated section.

In the second flight period the same orchard was divided into approximately one-acre blocks. Three treatments were assigned to each of three blocks in a Latin square design. The treatments were 3M-CM without a sticker, 3M-CM with a sticker, and Isomate-C+. The 3M-CM treatments were applied at 20 g AI/acre and the Isomate-C+ at 400 dispensers per acre. There was also a two-acre control plot located adjacent to the pheromone treated blocks. Two pheromone traps with a 1X lure were used to monitor moth activity in each block and the untreated control.

3M sprayable codling moth pheromone – Chelan: 3M-CM pheromone was applied to approximately two-acre blocks in an abandoned orchard near Lake Chelan. Treatments consisted of 1 g or 20 g AI/acre of 3M-CM, Isomate-C+ at 400 dispensers/acre and an untreated block. The 3M-CM treatments were applied to two two-acre blocks, the Isomate to only one block, and there was one untreated block. Each block was monitored with two pheromone traps baited with 1X lures and two traps baited with the DA kairomone lure. Traps were checked two times per week. In the second flight the orchard was divided into one-acre blocks. The experimental design and treatments were similar to that described for Royal Slope.

Consep sprayable codling moth pheromone: The Isomate-C+ was applied by hand to all blocks on May 1 at a rate of 200 dispensers per acre. The Consep sprayable pheromone (CSP) was applied through normal orchard airblast spray equipment in 80 gallons of water per acre. The intent was to apply 20 g AI/acre in the first spray and 10 g AI/acre in the subsequent sprays. The actual rate applied based on orchard spray records was 25.6 g AI/acre in the first and 12.8 g Ai/acre in subsequent sprays. Two applications of CSP were applied against each CM flight. A supplemental insecticide was applied to the CSP blocks in the first CM generation in response to captures of moths in traps and to reduce risk of testing a new technology.

Consep sprayable codling moth pheromone:
CM trapping – Delta-type pheromone traps baited with Pherotech CM SuperLures were used to monitor male moth activity. One trap was used for every 2.5 acres. In addition, Delta-type traps baited with the Trécé DA2313 kairomone lure was used to monitor CM male and female activity at a density of one every 2.5 acres. Traps were checked weekly. Pheromone CM SuperLures were changed every six weeks and DA2313 lures every eight weeks.

Fruit injury – At the end of the first generation 40 half-fruits from 50 trees per plot (10 trees in five rows - 1000 whole fruits) were examined for presence of codling moth injury. Just prior to harvest, 50 half-fruits from 40 trees per plot (1000 whole fruits) were examined for presence of codling moth injury. Edges of blocks were specifically monitored for fruit injury so reported damage levels likely overestimate fruit injury in the entire block.

3M sprayable leafroller pheromone – Royal Slope: A 3M sprayable pheromone was applied twice at 20 and 40 g AI/acre at leafroller biofix and four weeks later for each flight. Nu-Film 17 was added as a spreader/sticker at 1 pt/acre with each application of sprayable pheromone. Each experiment consisted of approximately 30 acres divided into three 10-acre blocks. The control block in each case was upwind from those treated with pheromone. There were two pheromone treated plots (20 and 40

g AI/acre). All blocks were treated the same for pests other than leafrollers as grower or consultant saw fit.

Each block was monitored with delta-style traps baited with either a high load (10 mg) or standard load (1 mg) lure. There were four traps of each lure-load per block (24 total for experiment). Traps were spaced equidistant from one another, alternating traps with different lure-loads. Traps were checked and rotated twice weekly, the number of leafrollers was recorded, and traps were placed/replaced within the top 3 feet of the tree canopy. Lures were changed once per generation. Trap bottoms were replaced when excessive wing scales and other debris had accumulated or at each lure change, whichever came first. The delta-style trap was used this year with a bait lure to assess adult flight (male and female) and mating success of females trapped. The bait lure consisted of a 10 ml polypropylene vial with a 0.33 mm-sized hole drilled in the lid and loaded with 5 ml of glacial acetic acid (aa). Ten bait traps per block, (30 per orchard), were spaced evenly throughout each treatment block. The lures were changed every four weeks. Bait traps were checked twice weekly and adults were collected and recorded. Mating success was determined by dissecting females collected.

Bud samples were collected at delayed dormant timing from each orchard to determine leafroller larvae overwintering population. A total of 200 buds per treatment were collected (50 buds per quadrant) and dissected in the lab. At petal fall, larvae were sampled by examination of at least 1000 shoots (10 shoots from 25 trees/quadrant) per block (treatment). In summer (mid- to late July), larvae were sampled again by examining at least 1000 shoots (10 shoots from 25 trees/quadrant) per block (treatment). A preharvest fruit injury assessment was made in mid- to late August. Ten fruits from 25 trees/quadrant (1000 fruits total per block) were visually inspected for leafroller fruit injury.

Leafroller hand-applied pheromone dispensers: Test 1 – This experiment was conducted at six different locations. Each experiment consisted of approximately 30 acres divided into three 10-acre blocks. There were two treatment plots along with an untreated control. All blocks were treated the same for pests other than leafrollers as grower or consultant saw fit. Pheromone block 1 was treated with 400 Isomate OBLR/PLR (80 mg) dispensers per acre. Pheromone block 2 was treated with 200 Isomate OBLR/PLR+ (250 mg) dispensers per acre. Dispensers were applied prior to biofix (first moth flight in the spring) and placed approximately 3 feet from the top of the trees.

Each block was monitored with delta-style traps baited with either a high load (10 mg) or standard load (1 mg) lure. There were four traps of each lure-load per block (24 total for experiment). Traps were placed in the top 3 feet of the canopy, spaced equidistant from one another, alternating traps with different lure-loads. Traps were checked twice weekly, the position rotated at each examination, and the number of moths recorded. Lures were changed once per generation. Trap bottoms were replaced when excessive wing scales and other debris had accumulated or at each lure change, whichever came first. The delta-style trap was used this year with a bait lure to assess adult flight (male and female) and mating success of females trapped. The bait lure consisted of a 10 ml polypropylene vial with a 0.33 mm-sized hole drilled in the lid and loaded with 5 ml of glacial acetic acid, (aa). Ten bait traps per block (30 per orchard) were spaced evenly throughout each treatment block. The lures were changed every four weeks. The bait traps were checked twice weekly, and adults were collected and recorded. Mating success was determined by dissecting females collected.

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fruits from 25 trees/quadrant (1000 fruits total per block) were visually inspected for leafroller fruit injury.

Test 2 – Similar tests were conducted in three other locations incorporating a fourth plot, (10-acre addition) treated with 200 Isomate OBLR/PLR (80 mg) dispensers per acre. This experiment satisfied all the conditions of the first.

Attract & Kill – leafroller formulation: IPM Technologies' Last Call-OBLR and Last Call-PLR were placed as droplets in pheromone traps and compared with standard lures for attraction of both species. Lures (Last Call or septa) were placed inside delta-style traps. Four traps of each lure type were used. Traps were checked every two to three days, moths counted and removed, and position of traps rotated at each inspection.

Last Call base matrix was used to formulate a leafroller attract & kill formulation with different concentrations (0.012, 0.032, 0.16, 0.8, 2.0 and 4.0%) of PLR and OBLR pheromone. A drop (50 mg) of the formulation was placed inside a mess container and then placed inside a pheromone trap. Leafrollers of the appropriate species were released in a field wind tunnel and the number of moths attracted to the trap determined. Pheromone traps with drops of the attract & kill formulations were placed in the field, and the number of wild moths captured in each concentration was recorded.

Scentry CM fiber pheromone:
Fiber mixing and application – The Scentry NoMate Fiber pheromone was mixed with Bio-Tac in a 5-gallon bucket prior to application via helicopter (Fig. 3). The combined NoMate Fiber and Bio-Tac was placed into a hopper attached to the helicopter. The fiber/Bio-Tac formulation was augured out of the hopper at a constant rate, and individual fibers covered with Bio-Tac were flipped off a high-speed spinning cone. The helicopter flew as low to the orchard canopy as allowed by physical constraints such as power lines or houses (Fig. 4). The objective was to apply fibers individually to the target, foliage or twigs of the orchard.

Codling moth – In the first codling moth generation three locations were established as evaluations sites. One location (Kucera/Alvino) was not used in the second generation because of low pest pressure, and a different location was substituted (Knapp Old Cherry/Organic 20). The first application of NoMate CM Fiber was made on April 28 to Kucera and May 4 to Knapp and Taylor Orchards. The second application was made on July 10 to Knapp and Taylor Orchards. The NoMate LR Fiber application was made on June 1. The distribution of fibers was evaluated following the second NoMate CM Fiber application.

CM trapping – Delta-type pheromone traps baited with Pherotech CM SuperLures or Trécé standard CM lures were used to monitor male moth activity. One trap was used for every 2.5 acres. In addition, delta-type traps baited with the Trécé DA2313 kairomone lure were used to monitor CM male and female activity at a density of one every 2.5 acres. Traps were placed following the application of the Scentry pheromone and checked weekly. CM SuperLures were changed every six weeks, standard CM lures every two weeks, and DA2313 lures every eight weeks.

Leafroller trapping – Delta-type traps baited with pheromone lures were used to monitor OBLR moths. Pheromone lures were supplied by Scenturion, Inc. and contained loads of 10 mg, 1 mg (standard) and 0.1 mg per lure. Two traps of each lure load were used in each block. Traps were placed following the Scentry LR NoMate Fiber application. Traps were checked weekly and the number of moths recorded. Lures were changed every six weeks.

Leafroller larval sampling – After egg hatch of the summer generation, August 7, was complete but prior to pupation, a sample was conducted to assess the density of leafroller larvae or feeding activity.

Twenty growing shoots were examined in each of 50 trees per plot. The number of shoots with leafroller larvae present or with feeding damage was recorded.

Fruit injury – At the end of the first generation 30 half-fruits from 50 trees per plot (750 whole fruits) were examined for presence of codling moth injury. Just prior to harvest, 50 half-fruits from 50 trees per plot (1250 whole fruits) were examined for presence of codling moth injury. At harvest 100 fruits from 25 bins per plot were examined and the number injured by insects, including codling moth and leafrollers, was recorded.

Results and discussion – 2001:
3M sprayable codling moth pheromone – Royal Slope: During the first flight period there was no real reduction in moth capture in the pheromone treated area relative to the untreated area. After the first generation there was no difference in the level of damage by CM in either treatment area.

In the second flight the Isomate-C+ treatment had the lowest moth capture relative to the 3M-CM treatments. The 3M-CM treatment without sticker had the least reduction in moth activity, followed by the 3M-CM treatment with sticker, and then the Isomate-C+. Moth pressure was very high, and the Isomate treatment only suppressed moth activity by about 80%.

3M sprayable codling moth pheromone – Chelan: During the first flight there was little suppression of CM activity by the 3M-CM treatments. The 1 g AI/acre rate suppressed moth activity about one week. The 20 g AI/acre rate suppressed moth activity for a slightly longer period, but the Isomate treatment provided the greatest degree of suppression.

In the second flight, the 3M-CM treatments with or without sticker suppressed moth activity by only about 60% but did so for almost 30 days. The Isomate treatment suppressed moth activity by 86% relative to the untreated control.

Conclusions: The 3M-CM sprayable pheromone has promise as a new technology for delivering pheromone; however, the new capsule technology does not seem to remain in the foliage or at least does not remain effective in shutting down moth capture. Continued research on the retention of the sprayable pheromone in the tree is needed for this new formulation.

Consep sprayable codling moth pheromone: Pressure by CM was low as indicated by capture of moths in either CSP or Isomate treated blocks at the Naumes Pateros Orchard. The average number of moths per trap per week for the entire growing season is shown in Table 1. Fruit injury after the first generation was low, as it was at harvest in most blocks. Actually, the highest damage was noted in the Isomate treated blocks at harvest. Almost all this injury was on the orchard border. The CSP formulation was easy for the grower to work with and, at least under the low pressure situations experienced at the Naumes Pateros orchard in 2001, performed as well as Isomate-C+ when supplemented with one insecticide. The pressure of CM in the 2001 trial location was not sufficient to ascertain how long the CSP applications suppressed CM flight or if suppression overlapped application intervals.

Table 1. Average moth capture (±SEM), accumulated moth capture and fruit injury by CM in blocks treated with ESP or Isomate-C+.

	Average moths per trap per week		Accumulated moths per trap		% CM fruit injury	
Block-Treatment	SuperLure	DA-lure	SuperLure	DA-lure	First	Harvest
C6-ESP	0.123±0.05	0.035±0.04	7	2	0.10	0.10
C3-Isomate	0.158±0.08	0.000±0.00	6	0	0.00	0.00
F4- ESP	0.224±0.10	0.132±0.04	17	10	0.20	0.00
F5&9-Isomate	0.395±0.09	0.197±0.06	30	15	0.60	0.88
F15- ESP	0.158±0.09	0.026±0.03	6	1	0.20	0.20
F17-Isomate	0.105±0.07	0.184±0.07	4	7	0.00	0.60

3M sprayable leafroller pheromone: Leafroller sprayable pheromone showed consistent reductions in pheromone lure trap catch for the obliquebanded and pandemis leafrollers at both rates when applications were made at the proper timings. Results showed that the higher rate (40 g AI/acre) provided more consistent reduction of moth activity compared to the lower rate (20 g AI/acre). Although there was consistent reduction in trap catch in many of the trials, there is no evidence of a reduction in larval populations using sprayable pheromone at either rate. Bait traps attracted significant numbers of adult moths this year in two of three orchards. There was no difference between the mating success of the untreated and sprayable pheromone blocks.

Leafroller hand-applied pheromone dispensers: All of the leafroller pheromone dispensers showed consistent reductions in pheromone trap catch in both flights for the obliquebanded and pandemis leafrollers at both rates. Although there was consistent reduction in trap catch in many of the trials, there is no evidence of a reduction in larval populations using any of the pheromone dispensers. Bait traps attracted more leafrollers than last season, (2000 - 279 moths; 2001 - 5,660 moths). In all hand-applied dispenser blocks there was a reduction in the percentage of mating success in the high rate pheromone block as opposed to the untreated.

Attract & Kill – leafroller formulation: Monitoring lasted for 45 days. The Last Call-PLR droplet attracted only 6% of the standard lure, and Last Call-OBLR droplet attracted only 10% of the standard lure. Improvement in the attractive ability of Last Call leafroller products is recommended to improve product efficacy.

In the field wind tunnel almost no moths were attracted to the attract & kill formulations containing 0.16% of pheromone or less. As the pheromone concentrations increased from 0.8 to 4%, moth captures increased but were always significantly less than captures in a trap baited with a 1X pheromone septum. Similar results were recorded when moths were trapped in orchards where traps were loaded with different concentrations of attract & kill formulations. Tests will continue in 2002, and this winter the pheromone release rate from the Last Call attract & kill formulation will be determined relative to the pheromone septum.

Scentry CM fiber pheromone:
The Scentry NoMate fiber pheromone formulations for codling moth showed some promise in suppressing moth activity in traps placed in treated orchards. Where there was high pressure from CM, suppression was not sufficient to prevent fruit injury (Knapp Orchard – Booster Pump block). In the second generation there was good suppression of moth activity in the Old Cherry block of the Knapp Orchard.

In the leafroller test the Scentry fiber pheromone suppressed moth capture in traps throughout the complete first flight compared to the untreated control. There was a lower density of leafroller larvae in one fiber pheromone treatment but not in the other compared to the control.

The application technology used in 2001 was not to the standards of the company, and better equipment to be used in 2002 should trials move forward. The uneven distribution of fibers in the plots was due in part to application equipment and in part to wind drifting the fibers. These are problems that can be overcome by using appropriate equipment and making treatments during early morning hours.

Budget:
Evaluation of sprayable pheromone and attract & kill for codling moth and leafroller control
Jay F. Brunner,
Project duration: This project has lasted three years and terminates with this report. A new proposal in this area is being presented.
Current year: 2002
Original budget request: $35,000

Year	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**	**TOTAL**
Total	35,000	35,330	16,280	86,610

Current year breakdown

Item	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**	**1999-2001**
Salaries	16031	15000	0	31031
Benefits (%)	4649	4950	0	9599
Wages	8400	10500	10500	29400
Benefits (%)	1344	1680	1680	4704
Equipment				0
Supplies	3576	2000	2000	7576
Travel	1000	1200	2100	4300
Miscellaneous				0
Total	35000	35330	16280	86610