

FINAL PROJECT REPORT**WTFRC Project Number:** ARS Project**Project Title:** ULV microencapsulated sex pheromones for codling moth**PI:** Alan Knight
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State/Province/Zip WA 98951**Cooperators:** Rick Hilton, Phil Van Buskirk, Doug Light, Tom Larsen, and Bill Lingren**Other funding Sources****Agency Name:** Suterra LLC
Amount awarded: \$20,000
Notes:**Total Project Funding:** \$56,000**Budget History:**

Item	Year 1: 2005	Year 2: 2006	Year 3: 2007 (extension)
Salaries	14,000	14,000	0
Benefits	2,250	2,250	0
Wages	6,000	6,000	0
Benefits	1,000	1,000	0
Equipment	1,000	1,000	0
Supplies	2,000	2,000	0
Travel	1,750	1,750	0
Miscellaneous	0	0	0
Total	28,000	28,000	0

Significant findings

2005:

- A season-long ULV pheromone spray program (4 – 6 sprays) was as effective as the use of 300 Isomate-C PLUS™ in apple or 200 Isomate-C tt™ dispensers in pear. Overhead irrigation did not reduce the effectiveness of the ULV spray program. However, moth catch was significantly higher early in the season in overhead-irrigated ULV-treated orchards.
- Addition of pear ester MEC at 0.25% did not improve the effectiveness of either the pheromone or pheromone plus Asana ULV sprays at mid-season.
- A 6-spray ULV program with Asana was highly effective for CM management. The addition of sex pheromone did not improve this program. Cutting the rate of Asana to 3 oz per acre appeared to be effective.
- Residues of Asana were all below the accepted 2.0 ppm threshold at harvest in blocks treated with six applications of the 6 oz rate.
- The effectiveness of the Asana program was likely due to both lethal and sublethal effects. Asana residues (1 – 2 ppm) reduced the fecundity of moths > 95%, but did not effect mating success.
- ULV Asana sprays flared mites, but levels were moderate and mite predators increased late in the season.
- Four ULV applications of Assail or Intrepid plus pheromone did not significantly reduced moth catches or fruit injury compared with pheromone alone or no pheromone in grower orchards. Pest mites were not disrupted in these blocks.
- The top and bottom of ULV sprayed apple leaves remained attractive for 28 d.
- The ULV spray deposits microcapsules on the top and bottom of leaves throughout the canopy of apple orchards.
- Leaf size directly impacted the density of microcapsules deposited.
- Increasing nozzle height (smaller spray angle) increased the relative deposition of capsules on the top versus the bottom of leaves.

2006:

- The effectiveness of a 5-spray ULV Checkmate® CM-F pheromone program was similar to 400 Isomate C PLUS in replicated 10-acre apple plots.
- The addition of either Assail or Asana to a ULV pheromone 5-spray program significantly improved the effectiveness of the pheromone alone program.
- The application of insecticides alone via a low volume application significantly reduced fruit injury.
- Mite populations were low in all treatments except the air blast applications of Asana. The ratio of predator mites to two-spotted mites was higher in all ULV insecticide treatments versus the air blast treatments.
- The ULV pheromone plus Assail program was highly effective against the white apple leafhopper.
- Laboratory assays suggest that Assail and Warrior are excellent materials to use as ULV treatments for adult codling moth.
- Traps baited with artificial leaves treated with 50 – 100 microcapsules were attractive for at least 3 weeks.
- The use of a visual detector triggered by tree trunks was used to increase the clumping of capsules on leaves (PULSV).

2007:

- Adding Assail (1.7 oz/ac) to the low volume sex pheromone spray increased the number of clean fruits by 10-fold in a six-spray seasonal program.
- Reducing the rate of Assail from 1.7 to 0.85 oz/ac improved control of codling moth by 50% in a five-spray seasonal program using sex pheromones.

- Pheromone emission from microcapsules was reduced 10% in laboratory assays when they were mixed with the high rate of Assail (1.7 oz/1.25 gallons).
- The use of both Warrior (3.0 oz/ac) or Assail (1.7 oz/ac) in a pear block treated with multiple applications of kaolin clay in Medford caused mites to flare but neither rate caused any mite problems in a pear orchard in Yakima not treated with kaolin.
- Season-long applications of sex pheromone plus Warrior (3.0 oz/ac) caused spider mites to flare in one out of six commercial apple blocks.
- Thinning sprays including carbaryl were shown to be disruptive of spider mite populations in an experimental apple block, but the seasonal program of low volume sprays of Assail did not disrupt spider mites and predatory mite populations recovered to high densities.

Results and Discussion

Growers in Washington State are interested in the use of a sex pheromone formulation that can be easily applied through their standard spray equipment. Unfortunately, the microencapsulated formulations of codling moth's sex pheromone when applied with air blast sprayer technology were found to be rather short-lived and expensive to use. The development of a low volume spray approach using the GF-120 sprayer has been able to significantly improve the performance of the MEC formulation, Checkmate™ CM-F in tests conducted since 2004. The low volume and low spray pressure application deposits 6-10-fold more microcapsules than an air blast application and creates attractive point sources (leaves) throughout the canopy of the trees. We hypothesize that this approach initially creates an effective camouflage of the virgin females' signals and then is effective for several more weeks due to competitive attraction of the leaves with high numbers of microcapsules. Flight tunnel tests showed that apple leaves with large number of microcapsules can remain attractive to male codling moths for 3 to 4 weeks.

The limitations of using the low volume spray applications of the MEC formulation in a seasonal program continue to be the impact of precipitation, particularly early in the season; and its reduced effectiveness in orchards with overhead irrigation systems, and the cost of having to apply 5-6 applications to cover the entire season. Currently, the low volume applications of sprayable pheromones for codling moth are applied on nearly 3,000 acres in the western United States. The primary uses of this product have been by growers to supplement their integrated programs for codling moth both spatially and temporally. For example, growers have applied the pheromone along the borders to improve control of codling moth in this particularly difficult area within orchards. Temporally, growers have applied the sprayable pheromone at periods of peak moth flight in either generation to improve the effectiveness of the pheromone emitted from arrays of hand-applied dispensers. Also some growers apply the sprayable pheromone at the end of the season to extend the effectiveness of their programs which are based on the use of either hand-applied dispensers or aerosol puffers. Future use of the sprayable pheromone is likely to increase as growers are forced to respond to issues of insecticide drift along the borders of their orchards and insecticide residues on fruit at harvest.

The concept of adding an insecticide to the low volume pheromone spray is a useful approach for growers. Current spray programs for codling moth are focused on ovicidal and larvicidal control and generally do not target the adult stage. Interestingly, both the neonicotinyls and synthetic pyrethroid classes of insecticides have excellent activity for codling moth adults. Both classes of insecticides produce direct mortality of moths at low rates and indirect effects that strongly reduce female moth fecundity. The mobility of codling moth adults within the canopy of orchards appears to be sufficient to allow moths to contact spray residues even when they are applied at rates as low as 1.25 GPA.

Four potential problems could occur with this approach. First, we have created spider mite flare-ups in some orchards sprayed with the concentrated insecticides. With Asana we were able to avoid mite problems by reducing rates from 6.0 to 3.0 oz/ac. Similarly, parallel studies by Dr. Tom Larsen using 1.0 oz/ac of Warrior have not created spider mite problems in treated orchards. Secondly, our recent finding that a reduced rate of Assail was more effective and that the higher rate adversely impacted the microcapsules is interesting. Further studies are needed to assess the interactions of the insecticide/pheromone mixture and select the most efficacious rates. Third, the evolution of insecticide resistance by codling moth continues to be a concern for growers. Populations of codling moth in Michigan and Pennsylvania have already been reported to have developed some resistance to Warrior following growers recent, and rapid use of this product. Resistance management strategies suggest using insecticide rotation and restricting use of selected materials to only one generation per season. These approaches should also be used when implementing the low volume management program. Fourth, is the concern that concentrating insecticides increases the likelihood that residues on fruit will exceed thresholds. However, apple fruits collected in 2005 from plots treated with six sprays of Asana at 6.0 oz/1.25 GPA did not exceed the established residue limit. This likely occurred because the last spray was applied 28 d before harvest. In general, growers can avoid this problem by not using these low volume concentrated sprays late in the season and by further reductions in the rates of insecticides applied.

At present, it is not clear which insecticides can be applied as low volume concentrated sprays from the ground. Currently, Warrior is the only material that growers have used in commercial orchards; however, the label for Calypso does not restrict applications based on a minimum water volume. In addition I am working with the manufacturers of Assail to further evaluate the potential for this approach with their product. Some of these problems can be resolved by increasing the spray volumes applied from 2.5 to 5 GPA. For example, this dilution may reduce the impact of the insecticide on the pheromone material and would likely improve coverage. Furthermore, when low volume sprays are only applied along the borders this increase will still allow large orchards to be easily treated with an ATV carrying a small spray tank.