FINAL PROJECT REPORT **YEAR**: 1
WTFRC Project Number: CP-13-102A

Project Title: Season-long protection of apples from codling moth using kairomonal mass trapping.

PI:	Peter Landolt	**Co-PI (2):**	
Organization:	USDA, ARS	**Organization**:	
Telephone:	(509) 454-6551	**Telephone**:	
Email:	peter.landolt@ars.usda.gov	**Email**:	
Address:	5230 Konnowac Pass Road	**Address**:	
Address 2:		**Address 2**:	
City/State/Zip:	Wapato, WA 98951	**City/State/Zip**:	

Cooperators: **Total Project Request:** **Year 1:** $29,000 **Year 2:**

Other funding sources: **None**

Budget 1
Organization Name: USDA, ARS **Contract Administrator: Chuck Meyers**
Telephone: (510) 559-5769 **Email address: chuck.myers@ars.usda.gov**

Item	2017		
Salaries			
Benefits			
Wages	$22,400		
Benefits	1,800		
Equipment			
Supplies	4,300		
Travel	500		
Plot Fees			
Miscellaneous			
Total	$29,000		

Note: Original proposal was for 2 years. Withdrawal of the second year of funding was requested by the PI.

OBJECTIVES

Objectives. The principal objective of this project was to demonstrate control of damage to apples by the codling moth in commercial apple orchard blocks using a kairomone lure in a Delta trap. The approach or research goal was to trap out enough female moths to prevent most oviposition and thus to prevent most attacks to the fruit.

SIGNIFICANT FINDINGS (for 2017 field season).

1. Mass trapping of codling moths using a kairomone attractant in the traps resulted in less damage/infestation of apples in treated plots compared to control plots in apple orchards with modest infestation levels.
2. Relatively large numbers of female and male codling moths were removed from treated plots, captured on the adhesive-coated liners of the Delta traps.

RESULTS AND DISCUSSION

Background: Work prior to this project showed the superior attractiveness to female codling moth of the combination of acetic acid, pear ester and N-butyl sulfide (Landolt et al. 2014). Additionally, we concluded that using an adhesive-coated surface (sticky trap) in place of a pesticide-treated surface for an attract-and-kill station was possible in commercial orchard settings where overloading of the trap liner surface is not severe. This approach is what has been called "mass-trapping" or "trapping out", and maintains the primary advantages of the attract-and-kill concept of using an attractant to bring pests to a discrete killing station. This approach has potential over cover sprays to reduce or replace insecticide use, and greatly reduce impacts on beneficial and other non-target insects. The mass-trapping approach has the additional benefit over pesticide baits of providing direct information on the insects removed, both pest and non-target.

Under the prior WTFRC project CP-13-102A "Codling moth attract-and-kill with kairomonal lures", experiments using a Delta trap in one-acre and 4-acre blocks of heavily-infested apple orchards, at a density of 50 traps per acre for ca 30 days, greatly reduced numbers of adult codling moths in monitoring traps, which we referred to as "knockdown". More importantly, percentages of apples that were damaged by codling moth were significantly less in the 4-acre plots with the 50 traps per acre, compared to the untreated plots (Jaffe et al. in preparation, WTFRC final report January 2017).

2017 Field Season. Methods and Approach. In the 2017 field season, under the current WTFRC project, the same methods generally were used as in the previous WTFRC project. Three aspects of this study differed from previous work.

First, rather than conduct tests for ca 30 days, which was intended to cover the flight period of a generation of codling moths, we conducted the test continuously from first moth flight until harvest. This involved setting up about 50 traps per acre in the 4-acre plots in early May and maintaining those traps until early September. Weekly trap maintenance involved counting and recording male and female codling moths in traps, removing moths and other insects if few in number, replacing liners that were dirty or with many insects captured, and occasionally replacing downed or damaged traps.

Second, rather than use apple orchards with codling moth populations that were uncontrolled as in previous tests, we used apple orchards with a history of damage and trap catch, but more modest codling moth populations.

Third, we deployed no traps in control plots. In earlier studies, we used kairomone, pheromone, and blacklight-traps to monitor numbers of moths in both treated and control plots. However, there was evidence that we were removing significant numbers of female codling moths with the monitoring traps in control plots. So, rather than compare trap catches (to determine knockdown) and damage to apples in treated vs control plots, we relied solely on assessing codling moth damage to apples.

2017 Field Season Results. In mid-season, following the end of the first moth flight, the percentages of apples that were damaged by codling moth were much less in plots with 50 traps/acre, compared to plots with no traps (Figure 1). The difference between damage to apples in treated vs control plots was stronger for the Parker site (ca 75 % less in the treated plot, and less dramatic for the Higgens site (ca a 55 % reduction). The Higgens site also had much less damage overall (<1 %) than the Parker site (up to 5+ %). Although there were individual apples that had more than one sting or hole (referred to below as damages), the percent of fruits damaged was not much less than the numbers of damages per fruit. That is, most damaged fruit had been attacked by one larva.

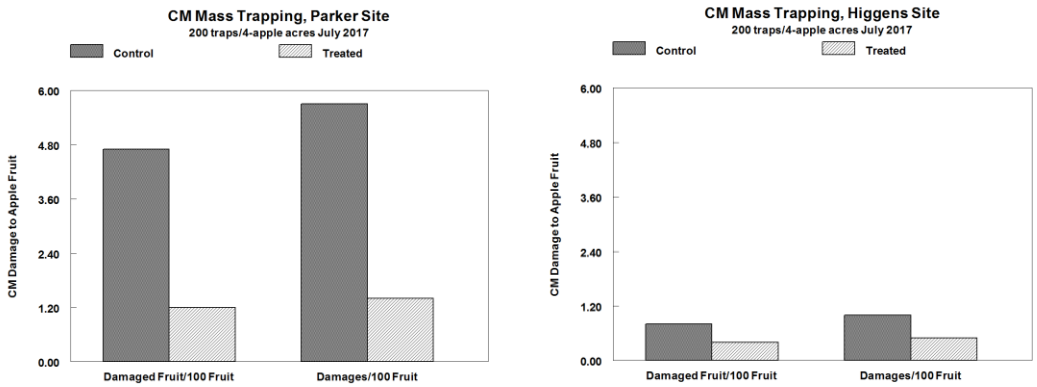

Figure 1. Amounts of damage to apple fruit by codling moths in orchard plots treated with 50 kairomone-baited traps per acre (Treated), or receiving no traps (Control). Observations of fruit were made in early July, between the end of the first adult generation and beginning of the second adult generation (flight).

At the end of the season, the percentages of apples that were damaged by codling moth again were much less in plots with 50 traps/acre (treated), compared to plots with no traps (control). This difference between treated and control plots held for both orchards. Treated plots had 75 % (Higgens) to 90 % (Parker) less codling moth-damaged fruit compared to control plots. At the Parker site, the percentages of apple fruit that were damaged were less at the end of the season compared to mid-season because of fruit thinning of both treated and control plots that took place in early August. No such thinning took place at the Higgens site.

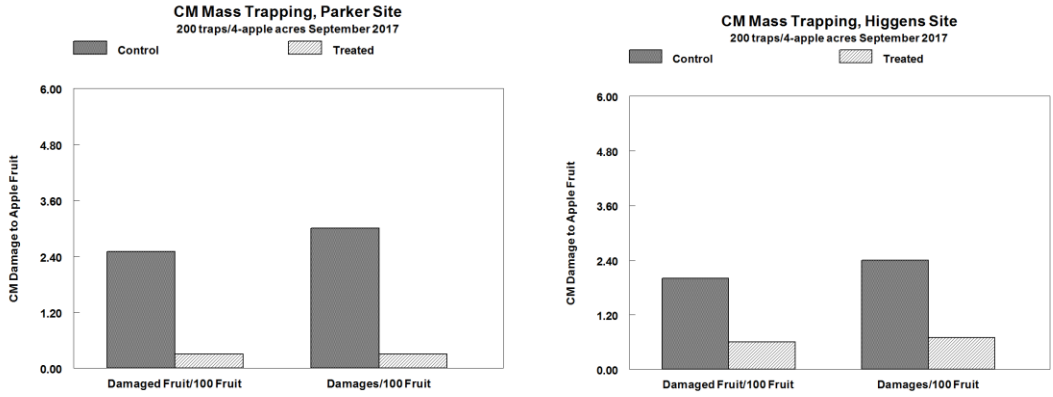

Figure 2. Amounts of damage to apple fruit by codling moth in orchard plots treated with 50 kairomone-baited traps per acre (Treated), or receiving no traps (Control). Fruit observations were made in late August into early September, near the end of the adult flight.

As in the prior 4-acre plot tests conducted for period of ca 30 days, the trap catch data shows that the lures were functioning well. Overall catch was somewhat male biased. Totals of 1314 females and 1721 males were removed from the Parker plot, and 294 females and 425 males were removed from the Higgens site. Captures of codling moths at the Parker site were much higher that at the Higgens site, in line with the much higher fruit damage at the Parker site.

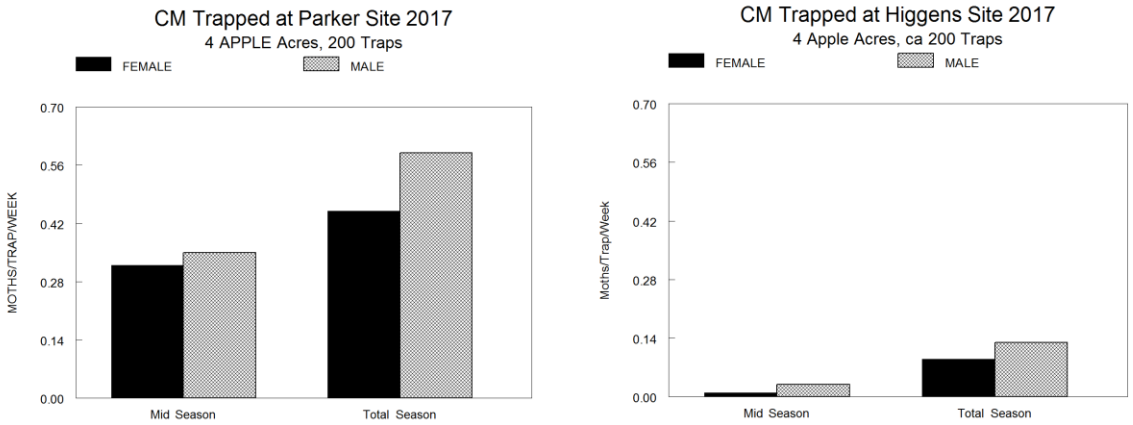

Figure 3. Average weekly numbers of codling moth males and females captured in Delta traps baited with a kairomone lure, for ca 200 traps per site and maintenance of traps for 16 weeks.

Discussion

The killing and removal of female codling moth from apple orchards has been a research goal, with prior trials indicating consistent suppression of populations of adult codling moth with these lures and traps in both one-acre and 4-acre plots. Success has been shown by the strong reductions in numbers of codling moth in kairomone- and pheromone-baited monitoring traps in plots with 50 kairomone-treated traps per acre. However, the ultimate objective of the work and a more relevant measure of success is the prevention of damage to the fruit. These trials, along with prior trials using very similar methods but for only 30 days at a time, show a good degree of protection of the crop with this mass-trapping approach, and over a broad range of codling moth populations.

Prior studies showed that females of all reproductive states/ages are attracted to our 3-chemical lure, and with the greatest value to the capture of females that have not yet oviposited or still possess much of their egg potential. These are represented in the trap catches as females that are unmated (no spermatophore) with abundant fat and no eggs, or females that are mated and have mature eggs. We expect then that the trapping of each of those females potentially prevents some oviposition and subsequent apple infestation. The additional trapping of males with the same lure may, or may not, have an impact on subsequent reproduction and damage to apples because a high percentage of males needs to be removed before female mating is impacted. This is why the research, and this discussion, focuses on the attractiveness of lures and effectiveness of traps for females.

These results indicate potential for this approach (mass trapping using lures for females) as one of the tools to use for management of codling moth. While the costs for labor and materials might be prohibitive for use of mass trapping as a long term stand-alone technique, it might be useful as a short term approach to reducing codling moth field populations to levels that can be managed with mating disruption. Additionally, such an approach may be helpful for localized problem areas,

sometimes called “hot spots”. Codling moth populations can become elevated on orchard borders, particularly where adjacent to or near uncontrolled populations such as urban/orchard interfaces, natural areas such as along creeks that may harbor “escaped” apple trees, or abandoned or poorly maintained orchards. A mass-trapping approach may be useful for such limited areas to keep larger orchard acreages under good codling moth control.

These studies and results do not suggest that the methods and materials used are either the best, or most cost-effective. Research conducted to date suggests that there is additional potential for alternative chemical blends in place of acetic acid plus pear ester and N-butyl sulfide. We have been working with alternative and much less expensive controlled release dispensers for the attractants by putting the chemicals in plastic sachets with specifications (type of materials, dimensions, film thickness, etc) to provide good release rates for long periods of time. Research results have indicated that other trap designs may be as effective in capturing attracted moths, while reducing the catch of certain non-target insects, and reducing the costs of traps. Most importantly, the approach worked (controlled codling moth) using these methods and this approach. Further improvements to the lure, the dispenser, and the trap will only further improve the effectiveness of the mass-trapping approach.

REFERENCES CITED

Jaffe, B. D., and P. J. Landolt. Field validation of a three chemical controlled release dispenser to attract codling moth (*Cydia pomonella*) (Lepidoptera: Tortricidae). Journal of Economic Entomology (submitted).

Jaffe, B. D., and P. J. Landolt. Control of codling moth by mass-trapping using a 3-component kairomonal lure. Journal of Economic Entomology (in review).

Landolt, P. J., D. M. Suckling, and G. Judd. 2007. Synergism of a feeding attractant and a host kairomone for the codling moth (Lepidoptera: Tortricidae). Journal of Chemical Ecology. 33: 2236-2244

Landolt, P. J., T. S. Davis, B. Oehler, D. Cha, and J. Brunner. 2014. N-butyl sulfide as a co-attractant with kairomones for male and female codling moths, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae). Environ. Entomol. 43: 291-297.

Executive Summary

Significant Outcomes
This study demonstrated control of damage to apples by codling moths with the use of 50 traps per acre, all baited with a kairomone attractant for female as well as male moths.

Summary of Findings.
Important specifications to the treatment were 50 traps per acre, in 4-acre blocks, an attractant comprised of acetic acid, N-butyl sulfide, and pear ester, an optimized controlled release dispenser system, Delta type traps with a sticky liner, and maintenance of traps and lures from first moth flight to just before harvest. These specifications were worked out or determined in earlier related WTFRC projects.
Reductions in damage to fruit by codling moth larvae were determined at mid season and end of season, by comparing treated and control blocks of apple orchards. End of season differences between treatment and control blocks indicated 75 to 90% reduction in damage to fruit by codling moth.
Direct comparisons of the kairomone attractant (acetic acid, N-butyl sulfide, and pear ester) dispensed from polypropylene vials and septa versus plastic sachets (bags) and septa, repeatedly showed a comparable performance of both controlled release approaches.

Future Directions.
Future directions could involve additional research, as well as technology transfer activities to make the technology and approach available to growers.
Research: There is reason to speculate that apple odor chemistry might suffice to replace the pear ester of the lure, for example, and if that is deemed advantageous. Additional field studies should be conducted to evaluate the technology and approach under a range of codling moth pest circumstances, such as “hot spots” caused by immigration from external sources, populations that have escaped control by mating disruption. Mass trapping with the kairomone lure should also be evaluated in combination with other soft approaches such as mating disruption, banding, virus, nematodes, and mass trapping of males with sex pheromone.
Technology transfer: Collaborative research and development will be needed with one or more companies. Such R & D will likely involve the pursuit of less expensive technologies (trap and lure), while maintaining effectiveness. Our demonstrations of efficacy of dispensing the attractant from inexpensive sachets to replace the polypropylene bottles, is one example of how that might work. Another possibility is to replace the Delta trap with a one piece disposable cylinder trap. Additional field studies will be needed to proof the efficacy of any controlled release dispenser or trap replacement technology. Products and their application to pest control are regulated and costs and efforts will be needed for licensing.