

## FINAL PROJECT REPORT

**Project Title:** Improved monitoring and lure and kill for codling moth management

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**Other funding sources:** None

**Total Project Funding:** \$21,000

### Budget History

**Organization Name:** ARS, USDA  
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Item	2018	2019
Equipment	-	
Supplies	12,000	
Travel	3,000	
Miscellaneous	-	
Plot Fees	-	
<b>Total</b>	<b>\$15,000</b>	<b>\$0</b>

### Budget 2

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Item	2018	2019
Travel (visit USDA lab June)	6,000	
<b>Total</b>	<b>\$6,000</b>	<b>\$0</b>

## RECAP ORIGINAL OBJECTIVES:

1. Develop two newly discovered attractant blends that can significantly increase catch of both sexes of codling moth to improve monitoring and increase the effectiveness of lure and kill technologies for this pest.
2. Field test and fine-tune the components of mass trapping for codling moth using a *hands-free approach* during the season.
3. Develop and evaluate *Zero-fly* netting for use against codling moth.

## SIGNIFICANT FINDINGS

- The **4-way K** lure was developed through extensive testing of host plant volatiles. This non-pheromone lure outperformed the standard pheromone lure used by the industry and caught 60-70% females
- The **4-way K** lure caught 4-fold more females than the previous best female attractant (pear ester plus acetic acid) and was effective in variable apple orchards with different cultivars, fruit loads, and throughout the season (green fruits, mature fruits, injured fruits, and fruits rotting on the ground).
- Lure development is continuing in South America.
- Mass trapping of codling moth using 24 combo plus acetic acid-baited bucket traps per acre were used to reduce levels of fruit injury 71% at harvest across four organic apple orchards. Traps were only serviced once at mid-season to replace the lures.
- The *Zero-fly* deltamethrin-impregnated netting was developed into a **Grey Ghost** and evaluated with moths in laboratory experiments. These tests demonstrated that the netting killed moths within 24 h with contacts as brief as 5 s. A strong sublethal effect on mating and egg laying occurred in moths that did not die within 24 h.
- The **Grey Ghost** remains toxic throughout the season and may last for more than one year.
- **Grey ghost**-treated plots had reduced moth catch in monitoring traps and 50% less fruit injury at midseason.
- Lures used with the **Grey Ghost** were not replaced and both the lure attractiveness and fruit protection declined after mid-season.

## RESULTS & DISCUSSION

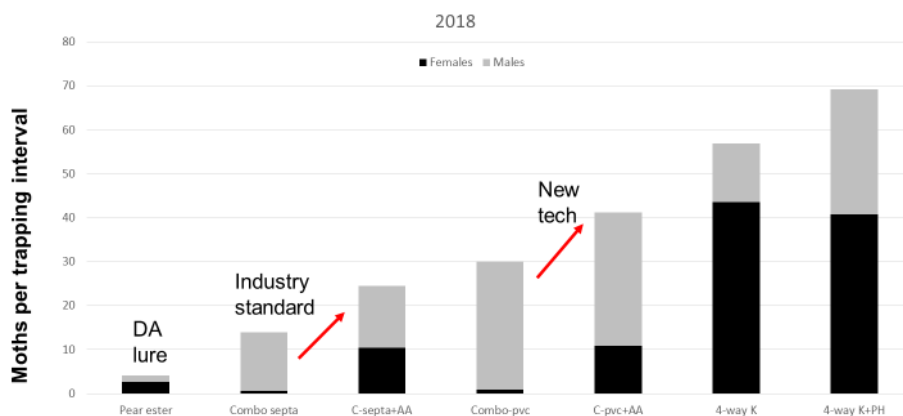
A series of studies were conducted during the 2018 season in a heavily infested set of apple orchards situated near Wapato, WA. Several host plant volatiles were evaluated in delta traps to see if they were attractive to adult codling moth. Individual compounds, binary, ternary, and quinary blends were compared. All of these compounds and blends were compared to the effectiveness of pear ester plus acetic acid lures as the industry best lure for female codling moth. Only the quinary blend outperformed the PEAA lure and caught nearly 4-fold more total moths and females with levels of females comprising as much as 80% of all moths caught (Figs. 1 and 2). This blend was coined **4-way K** because there are four kairomone compounds. Late in the season various modifications of this blend were evaluated with various substitutions of compounds. Just prior to the end of the season several additional volatiles were identified that could also be used in various substitutions. However, this work was incomplete and ongoing studies have been established in Uruguay and Chile to continue these studies.

The significance to the WA tree fruit industry of this discovery is tremendous. Identification of an attractant that is more powerful than sex pheromones and catches a very high proportion of female moths can benefit growers in several ways. The lure is very effective in orchards treated with sex pheromones for mating disruption as the traps are not disrupted. Enhanced capability to track female moths can allow significant improvements in timing sprays to target egg hatch. The lure does not draw moths into orchards and effective thresholds based on moth catch could be established. Data

from 2018 suggested the **4-way K** lure worked well in several cultivars, throughout the season, and in blocks with few fruit and heavy crop loads. Also, it worked whether the crop was injured, moderately injured, heavily injured and even when the orchard floor was littered with damage fruit. Trap height does not seem to be as important compared with sex pheromone lures, so traps could be placed at a lower and more convenient height in the orchard. The dogma in insect behavior research is that the best attractant makes the best disruptant of sexual behavior. Thus, it may be possible to develop improved mating disruption dispenser systems using one or more of these compounds. Experimental dispensers have already been formulated and will be tested in 2019. Finally, the tremendous increase in female catch afforded using the **4-way K** lure could make mass trapping extremely effective. Our results from last season using just 24 bucket traps baited with the Combo plus acetic acid lures (71% less injury) for an organic grower was exciting to both him and us, and perhaps these good results could be greatly improved using the 4X more potent **4-way K** lure.

The **4-way K** lure may also facilitate the eventual use of an attract-and-kill concept we explored in 2018. The *Zero-fly* netting was developed for battling malaria in third world countries and has been used effectively in research to manage the brown marmorated stink bug in Pennsylvania orchards. We developed the **Grey Ghost** which is baited with codling moth lures and hung in the canopy (Fig. 3). Our laboratory studies demonstrated that moths are not repelled and land on the netting in response to the lures. Moths typically walk on the netting for 1-60 s and often rest on the netting for longer periods. Forced touch tests demonstrated that as little as a 5 sec contact with the netting kills moths within 2 h and most moths by 24 h after contact ended. Sublethal effects are also pronounced with survivors unable to mate or to lay a full complement of eggs. A small field research study was established in 2018 using replicated 1-acre plots. We had hoped that the lures would last all season so once the **Grey Ghosts** were applied, we did nothing all season except check traps and sample fruit injury. Lures at mid-season were still effective, and moth counts, and levels of fruit injury were about 50% lower. However, by the end of the season no difference in fruit injury between the treated and untreated plots were seen and no difference in moth catches occurred in the two treatments. Lures near the end of the season only caught 30% as many moths as new lures. We consider these results to be interesting and will develop a method to attach a lure holder to the **Grey Ghost** that will allow lures to be more easily replaced at mid-season. We have a 3D printer at the laboratory to develop this device. We demonstrate that the netting does not lose any toxicity over the course of the season and could perhaps last more than one year.

**Figure 1.** Comparison of the 4-way K lure with industry standard lures.



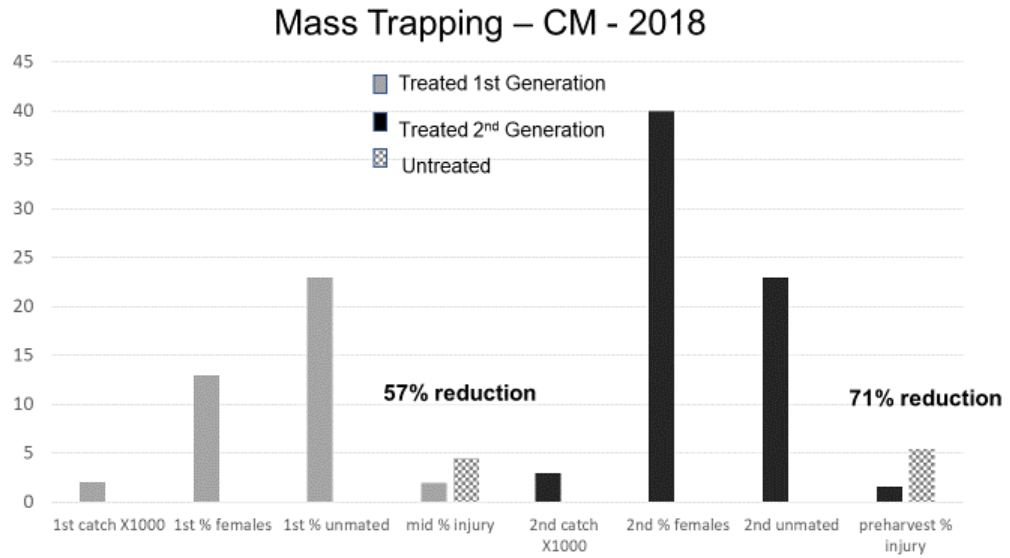
**Figure 2.** All the codling moths (males at top, females below) sorted and removed from the one liner on the right after only one night (21 July 2018) using the **4-way K** lure in combination with sex pheromone. *Note:* scale-less areas on liner are where the lures were placed.



**Figure 3.** Photograph of the **Grey Ghost** developed with *Zero-fly* netting for attract and kill of codling moth, 2018.



**Figure 4.** Summary of mass trapping experiments N = 4, using 24 bucket traps per acre baited with Combo plus acetic acid lures, Tieton, 2018.



**KEYWORDS:** codling moth, mass trapping, monitoring

**ABSTRACT:** A volatile blend was discovered that is effective for both male and female codling moth, *Cydia pomonella*. This blend catches more moths than the standard sex pheromone lure. Initial field trials demonstrated that this lure can be used to effectively reduce fruit injury through female removal.

**EXECUTIVE SUMMARY:** The *4-way K* lure was developed through extensive testing of host plant volatiles. This non-pheromone lure outperformed the standard pheromone lure used by the industry and caught 60-70% females. The *4-way K* lure caught 4-fold more females than the previous best female attractant (pear ester plus acetic acid) and was effective in variable apple orchards with different cultivars, fruit loads, and throughout the season (green fruits, mature fruits, injured fruits, and fruits rotting on the ground). Lure development continued throughout 2019 including evaluations of the effectiveness of this approach in grower's orchards, and further refinement of lures. Mass trapping of codling moth using 24 combo plus acetic acid-baited bucket traps per acre were used to reduce levels of fruit injury 71% at harvest across four organic apple orchards. Traps were only serviced once at mid-season to replace the lures. The *Zero-fly* deltamethrin-impregnated netting was developed into a ***Grey Ghost*** and evaluated with moths in laboratory experiments. These tests demonstrated that the netting killed moths within 24 h with contacts as brief as 5 s. A strong sublethal effect on mating and egg laying occurred in moths that did not die within 24 h. The ***Grey Ghost*** remains toxic throughout the season and may last for more than one year. ***Grey ghost***-treated plots had reduced moth catch in monitoring traps and 50% less fruit injury at midseason. Lures used with the ***Grey Ghost*** were not replaced and both the lure attractiveness and fruit protection declined after mid-season. Unfortunately, this netting has not been registered by the EPA, and future work with this material is on hold until the distributor is ready to move forward.