FINAL PROJECT REPORT

Project Title: Field testing of multi-component host plant kairomones for the codling moth.
PI: Peter J. Landolt, Research Entomologist and Research Leader.
Organization: USDA, ARS, Yakima Agricultural Research Laboratory, Wapato, WA
Cooperator(s): Jay Brunner, WSU, Wenatchee

Contract Administrator : Carolyn Yager, cyager@yarl.ars.usda.gov/509-454-6575

Objectives:

Project objectives:

1. Determine 2-component blends that are attractive to codling moth females in apple orchards.
2. Determine if reported multi-component blends are due to responses to 2-component blends.
3. Compare doses and ratios of a select kairomonal blend, to provide researchers with an improved lure for study.

2005 Objectives/goals.

1. Optimize beta farnesene as a codling moth lure.
2. Optimize an attractive ester blend as a codling moth lure.
3. Compare kairomones for efficacy in attracting male and female codling moth and the seasonal pattern of codling moth response to these kairomones.

Significant Findings:

1. A new GC-EAD study of wild codling moth antennal responses to diluted apple volatiles revealed significant antennal responses to a small number of compounds.
2. Statistically significant attraction of codling moth was demonstrated to -farnesene, E,E--farnesene, and the combination of ethyl benzoate and ethyl caproate.
3. Extensive and comparative field testing of the farnesenes, ethyl benzoate, ethyl caproate, and other apple volatiles indicated only weak attractiveness compared to the response of codling moth to pear ester.
4. Direct comparison of pheromone, pear ester, and the combination of both lures on back yard trees showed a consistent enhancement of male response with the combination of pear ester and pheromone (Figure).

Methods used:

Study 1.

Evaluation of GC-EAD active apple volatiles. In 2004 we used a GC-EAD set up to assess codling moth female antennal responses to volatiles of infested apple fruit, with the strategy of analyzing a serial dilution of samples of those volatiles. Looking at the most dilute sample that provided antennal responses,we saw a small set of consistent EAD-active compounds from these field collected apple fruit (nonanal, ethyl caproate, ethyl benzoate, bergamotene, and methylbutyl acetate). These compounds were tested in 2004 and in 2005 as partial and complex blends, to determine their attractiveness to codling moth in the field. One test evaluated a 5-component combination and blends with individual components dropped out. Other trapping tests evaluated single EAD-active chemicals (including compounds indicated by other laboratories to be EAD active), or multi-component blends. Compounds evaluated included beta farnesene, alpha farnesene, bergamotene, ocimene, linalool, pear ester, nonanal, methylbutyl acetate, ethyl caproate, and ethyl benzoate. Chemicals generally were

formulated in rubber septa at one mg loads, and were replaced every week or 2 weeks, depending on volatility. Pherocon 1C wing traps were used. Replicates of these tests were split between commercial orchards near Yakima, WA, and the Tukey Experimental Farm, WSU Pullman.

Study 2.
Beta farnesene optimization. Field tests were conducted in apple orchards to determine effects of changing the release rate, to compare trap designs, and to look for co-attractants with beta farnesene. The chemical was dispensed from vials for a high release rate range and rubber septa for a low release rate range. The trap designs tested were the Delta, wing, UniTrap or bucket, Sterling Smart, and pane traps. Trapping tests were conducted in both commercial and the WSU Tukey Experimental orchards.
Study 3.
Seasonal pattern of response and comparison of lures. The pear ester, beta farnesene, alpha farnesene, and ethyl benzoate with ethyl caproate were compared from April to late September. Traps were placed in commercial apple orchards and lures and traps were maintained through the Spring and Summer.
A season-long comparison was also made of the sex pheromone, the pear ester as a kairomone, and the combination of both lures placed in the same trap. Pheromone lures were Trece 1x lures, and kairomone lures were one mg pear ester on pre-extracted red rubber septa. Sterling Smart Traps were used for this experiment, and traps were placed in backyard and escaped or volunteer apple trees.

Results and Discussion:.
Study 1.
Testing of EAD active compounds. We showed in trapping experiments that beta farnesene, E,E-alpha farnesene, ethyl caproate with ethyl benzoate, as well as pear ester, are attractive to codling moth. However, the first four compounds have been only very weakly attractive, in comparison to pear ester.
Males responded significantly to the 5-component blend of nonanal, bergamotene, ethyl caproate, methyl benzoate, and methylbutyl acetate, as well as to the 4-component blends missing either ethyl caproate or methylbutyl acetate. Responses of females to these lures were not statistically significant, but greater numbers were in traps baited with the 5-component blend and the 4-component blend missing bergamotene.
Study 2.
Beta farnesene tests. The pane trap baited with beta farnesene captured the greatest number of codling moths, followed by the wing trap. Nearly no codling moths were captured in Multipher, red sphere, or Universal moth traps baited with beta farnesene. Numbers of male codling moths generally increased with the load (milligrams) of beta farnesene on the septum, up to the 10 mg maximum tested. With beta farnesene dispensed from vials, there was a negative correlation between numbers of males captured and vial hole size, indicating decreasing attractiveness with increased release rate. Numbers of males in traps with beta farnesene were increased with the presence of ethyl caproate and ethyl benzoate, but not synergistically.

Study 3.
Season-long response to lures. In the comparison of kairomones, by far the greatest number of codling moths were captured in traps baited with the pear ester, throughout both flights (Figure 2). In the comparison of pheromone and kairomone; throughout both flights the greatest numbers of codling moth males were in traps baited with the combination of pheromone and pear ester. In the first flight, numbers of males in pheromone traps were about 4X higher than in kairomone traps, but in the second flight these catches were comparable. Numbers of males in traps baited with both lures were 2 to 3 X higher than in traps baited with either pheromone or kairomone (Figure 1). Numbers of

females captured in traps baited with kairomone were similar to catches of females in traps baited with pheromone and kairomone together (Figure 1).

This work demonstrated codling moth attraction to several chemicals that are present in apple odor, including responses by females and by males. Although these responses were fairly consistent, they were also very weak in comparison either to codling moth attraction to pear ester, or attraction to the sex pheromone. Testing of combinations of chemicals did not show any significant positive interactions among compounds. These results are similar to that obtained earlier in the evaluation of a number of apple odor compounds tested in combination with the pear ester; none improved trap catch over that obtained with pear ester alone. It is possible that combinations or blends of compounds may be more attractive when released in a particular ratio.

The testing of doses of beta farnesene indicated improvement with 10 mg rather than the original one mg dose on a rubber septum, but also showed a decrease in attractiveness with the higher release rate range obtained with vial dispensers. The results of the trap design comparison, although not exhaustive, indicated that perhaps better results might be obtained using a pane or panel trap design for evaluation of kairomones. As with the pear ester, results with beta farnesene indicate a consistently stronger response by males than females, particularly in the first flight.

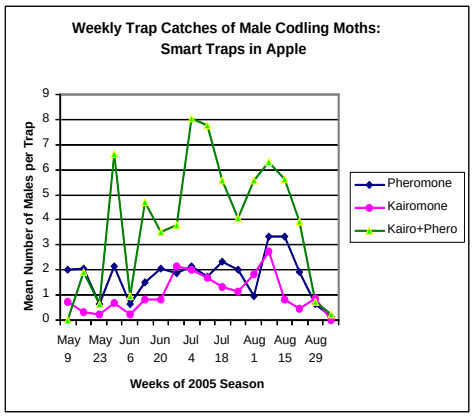
Other tests of blends, such as the combination of E,E-alpha farnesene, beta farnesene, linalool, ocimene, and hexyl hexanoate, did not produce significant results with blends. However, female codling moths were attracted by alpha farnesene, and males and females were sometimes attracted by beta farnesene. Other compounds were not attractive and did not enhance codling moth attraction to other compounds. Some were inhibitory at the levels tested (ocimene, linalool). Female response to alpha farnesene and female response to beta farnesene were not consistent. That is, results were statistically significant in some years or flights, and not in others. These are similar to problems experienced earlier with testing of pear ester. Possible confusing variables include competition from foliage and fruit odors that change with variety, pest levels, and season, as well as competition with other tested lures, and interaction with pheromone used in mating disruption.

Budget:
Project Title: Field testing of multi-component host plant kairomones
PI: Peter J. Landolt
Project Duration: 2003-2005
Current Year: 2005
Project Total (3 years): $53,200

Current Year Request: $18,100

Year	2003	2004	2005
Total	$17,500	$17,600	$18,100
Current year Breakdown	Year 1	Year 2	Year 3
Item			
Salaries	$14,300	$14,900	$15,400
Benefits			
Wages			
Benefits			
Equipment			
Supplies	$2,500	2,000	2,000
Travel	700	700	700
Miscellaneous			
Total	$17,500	$17,600	$18,100

Note: Funding from WTFRC Project "Codling moth Management with Pheromones: Key Unanswered Questions", permitted many more replicates as well as additional experiments to be conducted in tandem with this project. This included the costs of purchasing, purifying, and formulating much more of the kairomonal include replicates in Pullman, as well as Summerland, British Columbia, and Michigan.



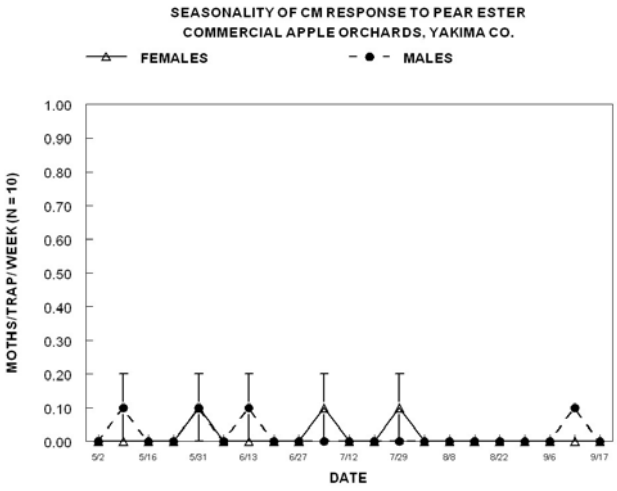
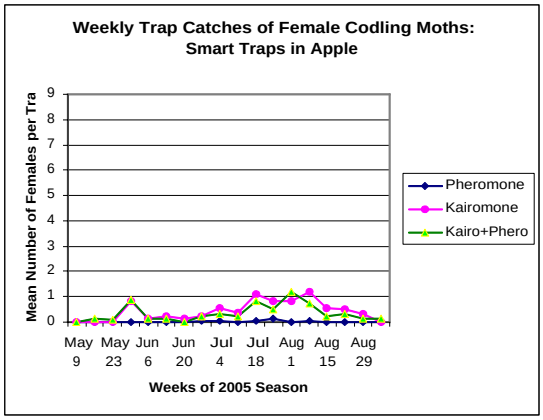


Figure 1 Mean numbers of male and female codling moth captured per trap, with traps baited with pear ester and codlemone. Back yard apple trees, Yakima County, 2005.



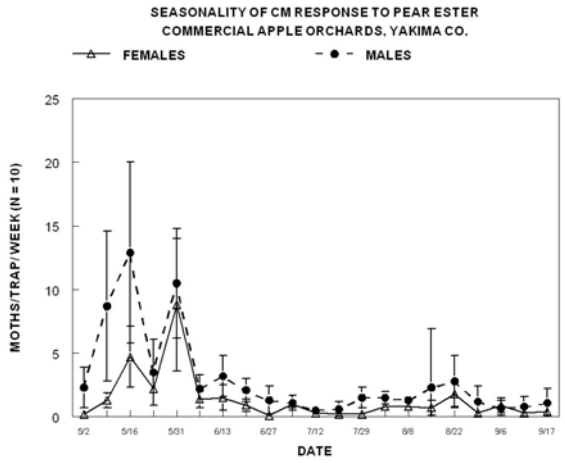


Figure 2. Mean numbers of male and female codling moths caught per trap, in traps baited with either pear ester or beta farnesene. Commercial apple orchards, Yakima, County, WA. 2005.