# FEMALE LURE TO IMPROVE MONITORING AND MANAGEMENT OF CODLING MOTH

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## ABSTRACT

Two binary lures, *MegaLure 4K* ™ and *MegaLure 5K* ™ were formulated by Trécé Inc. based on our characterization of a new more potent lure for both male and female codling moth. The first lure is black PVC and is loaded with pear ester, nonatriene, and linalool oxide or these three plus the addition of sex pheromone in the *4K* and *5K* lures, respectively. The second white membrane lure is loaded with acetic acid. Twenty volatiles were evaluated, and one new volatile was identified that was marginally more effective when substituted in the *4K* blend for linalool oxide. Studies in South America are continuing to evaluate new blends. Seasonal studies demonstrated that these new lures are effective for at least 8 weeks. The *4K* lure outperformed the *Combo* + AA binary lure and the *4K* lure caught more female moths than the *5K* lure. A new *Combo-P* + AA lure caught the greatest number of total and male moths. Clear bucket traps loaded with the *4K* lure caught 97-times more females than an orange delta trap baited with the *Combo* lure. Moth catch in 1-gallon milk jugs with two 3" holes was greater than in any commercial bucket trap type tested. Three sizes of milk jugs (gallon, half gallon, and quart) each with a pair of holes from 1.5 – 3.0" performed similarly. Increasing density up to at least 40/acre did not decrease the efficiency of individual traps. Traps can be loaded with mineral oil to retain moths though adding 5% vegetable glycerin improves the preservation of the catch and could diminish off-odors impacting catch. Biofix determination with either *4K* or *5K* lures in monitoring traps placed at head height (6') outperformed standard *Combo* lure-baited traps attached to poles and placed in the upper third of the canopy. 3,800 traps in 26 paired studies were established in apple/pear blocks across WA, OR, CA, and CO to evaluate the effectiveness of mass trapping to manage codling moth. All traps were baited with the *Combo-P* plus AA lures in the first half and these were replaced with either *4K* or *5K* lures at mid-season. All moths were counted (64,202) and a subsample of moths were sexed (39,510) and females were dissected (4,214) to determine their mating status. Fruit injury prior to harvest was up to 70% lower in the trapped blocks compared with the paired untrapped blocks. Similar results were obtained in both apple and pear.

## OBJECTIVES:

1. Evaluate the seasonal effectiveness of the new *4K* and *5K* lures with standard lures.
2. Test the effectiveness of other plant volatiles in various combinations compared with the *4K* and standard lures.
3. Evaluate the role of trap height on moth catches with the new *4K* and *5K* lures.
4. Evaluate the use of *4K* or *5K* lure-baited traps in mass trapping of codling moth in organic orchards.

**PROCEDURES**

Male, female, and total moth catch in orange delta traps baited with four different types of lures were evaluated. The four lures were provided by Trécé Inc. and included the standard grey septa *Combo DA* lure in combination with an acetic acid co-lure, the new *Combo-P* pvc lure in combination with acetic acid, the *Megalure 4K* comprised of two lures the acetic acid lure and a pvc matrix loaded with pear ester, nonatriene, and linalool oxide; and the *MegaLure 5K* which was similar to the 4K lure but had the sex pheromone added to the lure. Eight replicates of each lure were randomized in an untreated apple block beginning in late April. Traps were checked weekly for 11 weeks. The study was repeated in the second flight for 8 weeks in orchards either treated with pheromone or pear ester/pheromone dispensers or untreated.

Studies were conducted in all three States to assess whether the *MegaLure 4K* or *5K* could allow pest managers to monitor codling moth at a more convenient height than having to use poles. These studies also looked at the establishment of a Biofix to time the start of egg hatch of codling moth based on either male or female catch.

Several studies were conducted to improve trap performance. We compared seven types of traps baited with either the *Combo-P* + AA lures or the *Megalure 5K*. This study had five replicates with each lure and was run for one month. The second study evaluated the effect of trap density. Three replicates of three trap densities (15, 25, and 40 traps per acre) were established in 1-acre plots. All moths were collected from traps in each replicate after eight weeks, counted and sexed. A third study including 10 replicates examined an orange trap baited with a *Combo-P* lure versus the use of clear bucket traps baited with the *4K* lure. The liners in the delta trap were replaced after one week and the study concluded after two weeks. A separate study examined moth catch in clear bucket traps that were partially filled with either propylene glycol (PG), 20% PG in mineral oil, and 1.5% neem oil in mineral oil. Six studies were conducted to evaluate new volatile blends with 20 compounds being substituted for linalool oxide in the *4K* blend. Eight to 10 replicates were included in each study and moth catch was compared with the 3K (pear ester + DMNT + AA) and 4K blends.

Extensive studies were conducted to evaluate the use of female removal as a tactic to manage codling moth primarily in organic orchards. Blocks were placed within orchards treated with sex pheromone dispensers, including Isomate Flex, Isomate Mister, or Cidetrak CM-DA Combo PP dispensers or left untreated. All paired blocks were treated with the same growers' program. Plots (1--4 acres) were established with or without the supplemental use of female removal. All female-removal treated plots received 24 traps per acre. All traps were initially baited with the *Combo-P* + AA lures. At mid-season, traps were rebaited with either the *4K* or *5K* lures depending on our lure supply. All five pear studies used the *5K* lure. All moths were collected from traps at mid-season and prior to harvest. Moths were counted and a subsample of moths were sexed, and females were dissected to determine their mating status. Levels of fruit injury (800-2,400 fruits) were sampled in each of the paired blocks at mid-season and prior to harvest.

## RESULTS

All three new lures (*Combo-P, 4K, and 5K*) outperformed the standard, grey septa *Combo* lure during the first moth flight (Table 1). The *4K* lure caught the greatest number of female moths. A similar pattern was seen during the 8-week period during the second moth flight in MD orchards.

**Table 1 Mean moth catches in orange delta traps over an 11-week period during the first flight of codling moth in an apple block not treated with sex pheromone dispensers.**

| | Mean (SE) moth catch per trap per week | | |
|---|---|---|---|
| Lure | Males | Females | Total |
| Combo + AA | 4.0 (0.4)d | 2.8 (0.3)c | 6.8 (0.6)b |
| Combo-P + AA | 16.4 (1.1)a | 3.7 (0.4)bc | 20.1 (1.3)a |
| Megalure 5K | 10.9 (0.8)b | 5.7 (0.6)b | 16.7 (1.3)a |
| MegaLure 4K | 7.7 (1.0)c | 9.8 (0.8)a | 17.4 (1.7)a |
| ANOVA df = 1, 30 | $F = 36.47$, $P < 0.0001$ | $F = 30.74$, $P < 0.0001$ | $F = 21.35$, $P < 0.0001$ |

Studies demonstrated that the 4K lure can be used with traps placed low in the canopy without the use of poles (Table 2). This also avoids placing traps near MD dispensers. Male and female moths were caught 1-week earlier in the 4K traps and provided a better prediction of first egg hatch. Similar results were found in pears in Oregon to apples in Washington. Different results were reported from California.

**Table 2 Comparison of lures and trap height to monitor codling moth.**

| | Trap | Mean (SE) moth catch | | |
|---|---|---|---|---|
| Lure | height | Male | Female | Total |
| Combo-P | Low | 9.0 (6.0)b | 0.5 (0.5)b | 9.5 (6.5)c |
| Combo-P | High | 47.5 (4.5)a | 3.0 (1.0)b | 50.5 (3.5)b |
| MegaLure 4K | Low | 25.0 (2.0)b | 27.5 (1.5)a | 52.5 (0.5)b |
| MegaLure 4K | High | 77.0 (20.0)a | 31.0 (5.0)a | 108.0 (15.0)a |
| ANOVA | | Height: $P < 0.05$ | Lure: $P < 0.01$ | Height * lure: $P < 0.01$ |

Initial studies demonstrated that clear delta-shaped traps outperform the standard orange delta trap when baited with either the *Combo-P* or *5K* lures. Next, we showed how much progress has been made in capturing female codling moth by comparing a *Combo-P* lure in an orange delta versus 4K in a clear bucket trap (Table 3). The latter trap-lure combination caught 97-times more females than the standard trap-lure combination. A third study compared drowning solutions used in bucket traps. No differences were found with adding Neem oil to mineral oil but it did not preserve samples and allowed microbial growth. Future work will evaluate the addition of vegetable glycerin (organic approval is likely) as a preservative added to the oil.

**Table 3 How much better can we catch female codling moths?**

| | | Mean (SE) catch per trap | | |
|---|---|---|---|---|
| Trap | Lure | Male | Female | Total |
| Clear bucket | 4K | 194.6 (15.2)a | 289.7 (30.7)a | 484.3 (42.8)a |
| Orange delta | Combo | 98.2 (10.1)b | 3.0 (0.8)b | 101.2 (10.8)b |
| ANOVA df = 1, 18 | | $F = 30.41$ | $F = 262.5$ | $F = 116.9$ |
| | | $P < 0.0001$ | $P < 0.0001$ | $P < 0.0001$ |

Studies were conducted early in the season to compare homemade traps with several commercial non-saturating traps (Table 4). This included a clear peanut butter jar with two 2" holes and milk jugs with two 3" holes. The milk jug caught the greatest number of females and total moths.

**Table 4 Trap comparisons with the MegaLure 5K, N = 5, May 2019.**

| | Mean (SE) moth catch per trap | | |
|---|---|---|---|
| Trap, N = 5 | Male | Female | Total |
| Mini bucket – green/clear | 54.0 (8.2)ab | 74.6 (6.2)bc | 128.6 (11.3)ab |
| Homemade clear jar | 84.4 (12.7)ab | 83.6 (5.2)ab | 168.0 (15.7)ab |
| Clear bucket | 55.2 (15.8)b | 79.2 (13.5)bc | 134.4 (29.2)ab |
| Homemade milk jug | 133.0 (32.1)a | 116.2 (20.3)a | 249.2 (50.0)a |
| Green/Yellow/clear bucket | 48.0 (5.2)b | 41.4 (6.7)c | 89.4 (9.5)b |
| Green/white bucket | 60.2 (9.6)ab | 70.0 (15.2)bc | 130.2 (23.6)ab |
| All green bucket | 46.0 (9.2)b | 45.6 (7.9)bc | 91.6 (16.1)b |
| ANOVA df = 6, 28 | $F = 3.37$ $P < 0.01$ | $F = 8.69$ $P < 0.01$ | $F = 4.05$ $P < 0.01$ |

Limited studies were conducted with three sizes of milk jugs with a range of hole sizes. No clear pattern was found in these tests and the three jug sizes with a range of hole sizes were significantly more effective than the clear bucket trap.

The key to the effectiveness of FR technology is the ability to remove as many virgin females as possible. However, it is important to match the number of traps (cost of program) with the pest threat. Our initial trap density is based on a consideration of potential cost and earlier work on the range of activity of pear ester on moth catch. Our studies examined three trap densities, 15, 25, and 40 per acre. We found that female catch per trap only declined slightly across these three densities. This shows that adding additional traps is cost effective and should be used to treat higher moth densities.

We evaluated 20 new volatiles in combination with pear ester, nonatriene, and acetic acid. One candidate was found that outperformed the current 4K blend. Further studies are in place in South America this winter to examine various blend substitutions and this new volatile. We also found several volatiles associated with rosy apple aphid damage that reduced moth catch and field evidence that codling moth behavior is severely disrupted in heavily aphid-infested

orchards. Further studies will address the use of repellent blends to disrupt moth sexual behaviors.

The project was able to work with growers in four states and helped to establish 26 paired studies. Three groups of these studies are presented in Table 5 as six apple orchards in the Yakima Valley, five pear orchards in CA, OR, and WA, and six apple orchards situated between Quincy and Tonasket. Pest pressure was deliberately high in nearly all of these blocks and growers all used their typical organic spray and MD programs. Data showed that switching from the *Combo-P* + AA lure to the *4K* or *5K* lure at mid-season significantly increased the proportion of females caught. Fruit injury across the paired blocks ranged from zero up to 70% lower in the block trapped. The two trials in northcentral Washington that had no difference in fruit injury between the paired blocks were likely the result of the traps being deliberately placed at the higher end of a pest gradient in the orchard. Thus, the equal results across the paired blocks showed that the traps were able to reduce the 'hot spot' down to the background level in the orchard.

**Table 5. Summary of field trials using female removal technology to manage codling moth.**

| | | Range among trials | | | | |
|---|---|---|---|---|---|---|
| Region, # trials | Crop | Moths per trap | Prop. female | Prop. virgin female | % fruit injury | Prop. reduction in injury |
| Yakima, 6 | Apple | 15 - 56 | 0.11 – 0.76 | 0.25 – 0.65 | 0.5 – 3.1 | 0.41 – 0.76 |
| CA/OR/WA, 5 | Pear | 3 - 24 | 0.11 – 0.73 | 0.00 – 0.51 | 0.3 – 8.2 | 0.34 – 0.75 |
| Northcentral WA, 6 | Apple | 11 - 36 | 0.34 – 0.79 | 0.07 – 0.45 | 0.2 – 3.2 | 0.00 – 0.69 |

Table 6 shows the pear data broken out for each of the five orchards. The studies in Oregon and California were all in blocks not using sex pheromones for mating disruption and you can see very few virgin females were caught. Using the 5K lure increase the proportion of females trapped later in the season. Levels of fruit injury were consistently lower with the traps across all five blocks.

**Table 6. Summary of five pear orchards across three western States treated with female removal (FR) technology for codling moth management, 2019.**

| | | 1st Flight | | | | 2nd Flight | | | |
|---|---|---|---|---|---|---|---|---|---|
| Orchard | MD type | Moths per trap | Prop. female | Prop. virgin female | % injury FR vs. UTC | Moths per trap | Prop. female | Prop. virgin female | % injury FR vs. UTC |
| CA1 | None | 3.7 | 0.41 | 0.26 | 2.0 / 3.6 | 8.3 | 0.65 | 0.08 | 5.0 / 25.0 |
| CA2 | None | 1.5 | 0.11 | 0.25 | 2.5 / 4.8 | 1.0 | 0.70 | 0.00 | 1.6 / 5.1 |
| CA3 | None | 6.5 | 0.48 | 0.28 | 10.5 / 21.9 | 8.3 | 0.57 | 0.07 | 11.2 / 19.7 |
| OR1 | None | 20.5 | 0.62 | 0.28 | 0.00 / 0.56 | 3.9 | 0.73 | 0.28 | 1.53 / 5.40 |
| WA1 | Flex | 4.0 | 0.42 | 0.51 | 0.07 / 0.30 | 1.1 | 0.47 | 0.00 | 0.33 / 0.50 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mean** | | **7.2** | **0.41** | **0.32** | **3.01 / 6.23** | **4.5** | **0.62** | **0.09** | **3.93 / 11.14** |

## DISCUSSION

Tremendous progress was made during 2019 in the development of female removal as a viable tactic to manage codling moth in problem organic blocks. This progress is foremost based on our discovery in 2018 of a new more potent female attractant blend, now coined *MegaLure 4K*. A range of studies were conducted early in the summer to examine various factors critical to improving the effectiveness of female removal, including lure type, trap type, trap density, drowning solutions, and identification of new attractants. Growers will directly benefit from these extensive studies and the effectiveness removing female codling moths achieved next season should be even greater. However, in 2019 the new lures could only be used over the second half of the season. Also, we learned that the 5K lure caught fewer females than the 4K and this lure will not be further evaluated in subsequent trials.

Beginning in 2020 the *Megalure 4K* lure will be available for growers to use over the entire season. This lure catches 3x the number of females as the *Combo-P* + AA. Trapping grids can be improved from this year and treated areas in each block should be expanded to cover the entire area of moderate to high pressure codling moth. Also, trap density will be better matched to pest pressure.

Growers in 2020 can use any trap design, including delta traps, but non-saturating designs such as bucket traps require less maintenance. Milk jugs appears to be a lower cost (< $1 each) and more effective approach and are available in a range of sizes. We also expect that plastic jugs can be reused a few times and hopefully recycled at the end of their useful life. Eliminating the use of Neem oil as an antimicrobial agent and switching to vegetable glycerin will likely improve the performance of traps, perhaps by 25%. While, fruit injury from codling moth achieved in trapped blocks were up to 70% lower than in the comparison untrapped blocks, our data suggests that adopting the suite of improvements validated during the 2019 season will further improve the program as much as 4-fold next season.

Female moth removal would appear to be a more rational approach to manage codling moth than trying to prevent moth mating or to expect wild moths to mate with mass-reared Canadian sterile variants. Every female codling moth, whether virgin or mated, caught in a trap is no longer able to lay eggs in the grower's orchard and is no longer producing larval offspring intent on fouling fruit to munch on fruit seeds. Thus, with some accuracy, it is possible, based on the known biology of this pest, favorability of the weather, and the value of individual fruits to assess the return to the grower of removing female moths from their orchard. We have prepared a simple spreadsheet that includes the number of eggs laid per female in cool/wet or warm/dry springs and for either two or three moth generations per season. Values for life stage mortalities are added to the model. The price paid to growers for individual fruits is the final variable and we have considered a return of $0.05 or $0.25 per fruit. This simple and straightforward analysis suggests that the removal of a single female codling moth early in the summer can be worth $2 to 43 or $34 to 697 if the pest has two or three generations, respectively. One real-world example from an

organic apple block in Tieton with two generations found that the value of individual traps ranged from $7.50 to $750 depending on the moth reproduction prevented and apple price. Clearly, this approach makes economic sense to pome fruit growers!

## BUDGET REQUEST

Budget Year: 2019

| | Instar Biologicals |
|---|---|
| Salaries and benefits | - |
| Lab/field assistance | - |
| Employee benefits | - |
| Supplies and expenses | 4,000 |
| Equipment | - |
| Travel | 2,000 |
| TOTAL | 6,000 |

Budget Year: 2020

| | Instar Biologicals |
|---|---|
| Salaries and benefits | 4,000 |
| Lab/field assistance | - |
| Employee benefits | - |
| Supplies and expenses | 3,000 |
| Equipment | - |
| Travel | 3,000 |
| TOTAL | 10,000 |

Total Budget: 2019-20

| | Instar Biologicals |
|---|---|
| Salaries and benefits | 4,000 |
| Lab/field assistance | - |
| Employee benefits | - |
| Supplies and expenses | 7,000 |
| Equipment | - |
| Travel | 5,000 |
| TOTAL | 16,000 |

_____ _____

Originator's Signature Date

LIAISON OFFICER _____ Date _____