Codling Moth Monitoring in Mating Disrupted Apple Orchards: Development of Trap Thresholds and Prediction of Fruit Injury 2007

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Justification and Background:

Many Utah apple growers utilize pheromone mating disruption to lower codling moth populations and allow integration of lower toxicity insecticides into their pest management programs. Monitoring codling moth adult densities throughout the season is essential to evaluating the success of mating disruption and insecticide treatments. More information is needed on the attractiveness of commercially available codling moth lures in orchards with mating disruption. Development of useful trap thresholds and predictive relationships for fruit injury will empower Utah apple producers to effectively implement mating disruption of codling moth to their full advantage.

Lures based solely on the codling moth female sex pheromone (codlemone) include the standard release rate or 1X lure and the high-load or 10X lure. Codlemone is released by the female moth and is only attractive to the male. The 1X lure was developed for monitoring moths in non-mating disrupted orchards. The 10X lure was developed to release ten-times the rate of codlemone so as to be attractive to moths within a background of pheromone from mating disruption dispensers. A non-pheromone lure was recently developed based on a volatile chemical released from ripening pears. This pear ester has been nicknamed DA and is attractive to both male and female codling moths. The DA lure contains exclusively the pear ester. The DA-Combo lure contains both the pear ester and a high load of codlemone.

Objectives:

1. To evaluate four types of lures for capture of codling moth adults in apple orchards treated with pheromone mating disruption. To compare trap catch among lures across the growing season and for each codling moth generation.
2. To develop trap thresholds to determine when supplemental insecticide treatments are needed.
3. To develop a predictive relationship between fruit injury and trap catch for the effective codling moth lures.

Methods:

Four types of codling moth lures [1X, 10X, DA, and DA-Combo (hereafter referred to as Combo)] were evaluated for their efficacy in detecting adult activity in 12 apple orchards in Utah County (in Payson, Santaquin, Genola, and West Mountain). Biofix (first catch) of codling moth occurred from April 26-29 in the 12 orchards. Mating disruption (MD) pheromone dispensers were applied to orchards from late April to early May.

Test lures were placed individually in large Delta traps. Each lure was replicated three times in a randomized block design in each orchard for a total of 12 traps in each orchard and 144 traps across the 12 orchards (36 replicate traps with each lure). Traps were first placed in orchards from May 1-9. Traps were checked weekly through mid July and then every one to four weeks until September 19. Each time traps were checked codling moths were counted and collected into vials with Histoclear to dissolve the adhesive (DA and Combo baited-traps only; 1X and 10X lures only attract males). Trap positions were rotated systematically on each visit to avoid biases of trap position on moth catch. Lures were replaced according to manufacturer recommendations: every three weeks for 10X lures (red septa) and every eight weeks for 1X, DA, and Combo lures (long-life, gray septa). The sticky trap liners were replaced as needed after they became filled with moths and/or debris.

Following completion of the first and second generations of codling moth egg hatch (on July 11 and August 16, respectively), 400 fruit were visually inspected in each orchard for surface stings and larval entries. Fruit with deep stings and suspect larval entries were cut open to verify the type of injury. The percentage of fruit with stings and entries was determined.

Moths in vials were returned to the laboratory where the gender of adult moths was determined based on the presence of claspers (males) or a heart-shaped oviposition pad (females) on the tip of their abdomens. The abdomens of females were dissected to check for the presence of a spermatophore (sperm packet). If present, the number of spermatophores was counted to determine if the female had mated one or more times. If a spermatophore was absent, the female was recorded as unmated.

To compare attractiveness of the four lures, the number of codling moths caught per week over time and cumulative mean moth captures for each generation and the season total are presented. The number of male, female, and female mated moths caught in DA and Combo-baited traps across time are also presented. Fruit injury was regressed upon trap catch for each lure type for each first and second generation and for the season total. The ability to predict fruit injury from trap catch and determination of trap thresholds for the different lures is discussed.

Results:

Across all orchards the highest number of moths was caught in Combo-baited traps for all three generations (Fig. 1). This trend held true when orchards were separated for each of the four cooperating growers as well (Fig. 2A-D). Trap catch was least in 1X-baited-traps and in the middle for DA- and 10X-baited traps. In 10X-baited traps, more moths were caught during the second and third generations than during the first (Fig. 1).

Based on a degree-day model for codling moth development, moth flight for the first generation ended on approximately June 20. The second generation moth flight ended by August 5 and third generation ended by approximately September 15. Moth flight patterns most closely tracked generations and expected flight peaks for the Combo-baited traps (Figs. 1 and 2A-D).

Adult capture in traps baited with all lures had an initial peak within the first two weeks after traps were placed in orchards (early to mid May) (Fig. 1). This may have been partly caused by high moth numbers before MD dispensers were placed in some orchards. MD dispensers were already in place in some orchards when trapping began on May 1, so this early peak may in part be caused by high adult emergence and activity during early and mid May.

More male than female moths were caught in traps baited with both DA and Combo lures (Figs. 3 and 4). More male moths were caught in Combo- than DA-baited traps. Detection of mated females is important to assessing if MD is preventing mating and thus egg-laying. Mated females were detected with both DA and Combo lures. Slightly more mated females were caught in Combo-baited (Fig. 4) than DA-baited traps (Fig. 3). Dates when the most mated females were caught were early in the first generation in mid to late May, late in the second generation in early August, early in the third generation in mid August, and late in the third generation in mid September. Females that had mated multiple times were detected on two dates in DA-baited traps (Fig. 3) and on three dates in Combo-baited traps (Fig. 4). All of the multiple-mated females were detected in August during the second and third generations.

For each orchard the cumulative number of moths caught in traps baited with the four lure types was calculated for each of the three codling moth generations, totaled for the season, and compared to the percentage of apple fruits injured by codling moth larvae (stings, entries, and total injury) (Table 1). Cumulative moth counts were greatest in the first generation for most of the lure types in most orchards. Cumulative moth captures dropped off substantially by the second and third generations in most orchards. Cumulative moth counts in generations two and three remained above 10 in Grower D/Gala for all four lure types and in Grower D/Red Delicious and Red Delicious2 and Grower C/Golden Delicious for the Combo-baited traps only.

Most of the codling moth injury was due to stings rather than entries (Table 1). In most orchards more stings were observed following the first than second generation. Percentages of fruit injured by both stings and entries for the season (first and second generation results combined) were between 5.0 and 10.5% for nine of the 12 orchards suggesting that levels of injury were similar across most orchards.

Regression of fruit injury (stings and entries) onto trap catch was significant ($p < 0.05$) for 10X-, DA-, and Combo- baited traps for the first generation and cumulative season total. Trap catch in 1X-baited-traps was not significantly related to fruit injury for any generation. The best fit of the injury data (highest r^2 values) were for DA and Combo lures during the first generation (p = 0.0008, r^2 = 0.22; p = 0.0006, r^2 = 0.23, respectively) (Figs. 5 and 6). For both of these relationships the intercept [point where the regression line crosses the y-axis (percentage fruit injury)] was 3.8-3.9 and the slope of the regression line was 0.1-0.3. The slope of the line implies that fruit injury increased by approximately 0.2% for every moth caught in DA- and Combo-baited traps. These results are similar to those found in a similar study in 2006 where the relationship was 0.1% injury for Combo-baited traps. A y-intercept of approximately 3.9% indicates that fruit injury begins before moths are detected in traps. Therefore these data are not fully accurate, but a significant regression relationship supports that there is a linear increase in fruit injury with increasing moth capture in DA- and Combo-baited traps.

Development of action thresholds to indicate when supplemental insecticide sprays are needed have been evaluated in the Pacific Northwest (Brunner and Gut 1996 and Knight et al. 2006). Guidelines recommended for a high-load trap (10X lure) at a density of one trap per 2.5 acres is a cumulative catch of 4-10 moths (Brunner and Gut 1996). Knight et al. found that thresholds of 1-2 moths for DA traps and 2-4 moths for 10X traps reduced control failures while avoiding unnecessary spraying. In this study, grower cooperators did apply insecticide sprays when they felt that trap catch exceeded their personal thresholds. Therefore evaluation of action thresholds in this study are not in the absence of supplemental insecticide sprays. Excluding the high trap catch during the first two weeks of the study and using a threshold of 5 moths, Grower A orchards only exceeded this threshold late in the second generation for the Combo lure (Fig. 2A), Grower B orchards did not exceed the threshold (Fig. 2B), Grower C orchards exceeded this threshold three times for the Combo lure and once for the DA lure (Fig. 2C), and Grower D orchards exceeded the threshold four times for the Combo lure and three times for the 10X lure (Fig. 2D). Lowering the threshold to 2 moths and assessing additional times when this threshold was exceeded: there were none for Growers A and B and multiple times for each Grower C and D for DA, 10X, and 1X lures. Comparing these action threshold recommendations to fruit injury assessments (Table 1), only Grower D/Gala orchard reached 1.0% fruit injury from larval entries. Injury levels in the other eleven orchards would likely be considered acceptable to most apple growers in Utah. Therefore, a threshold of 5 moths for Combo- and 10X-baited traps seems reasonable. A lower threshold of 2 moths for DA-baited traps also seems reasonable to keep larval entries below 1.0%.

Conclusions:

Combo-baited traps caught the most moths in all orchards and tracked codling moth generation cycles and peaks the best in combination with a degree-day model. The ability to predict fruit injury from trap catch was the best for both DA and Combo lures. The relationship of an increase of 0.2% fruit injury for every moth caught in a DA- or Combo-baited trap was similar to results from 2006 for Combo lures (0.1% increase for every moth). The Combo and DA lures performed better than 10X lures in predicting fruit injury. The 1X lure was not effective and is not recommended for use in MD orchards.

DA and Combo lures have the advantage of attracting female moths and providing the orchard manager with information on female moth activity. However, the moths must be sexed and in order to determine mating status of females, the abdomen must be dissected and presence of spermatophore(s) determined. The gender of moths on sticky trap liners can be determined by a trained person with the aid of a 15-20X magnification hand lens. Determination of female mating status is more difficult and may require the aid of a microscope. Therefore the utility of female moth information is limited unless the pest manager learns to perform these techniques.

Attempts to validate or refine trap action thresholds were limited because of the application of insecticide sprays to the study orchards, but it appears that thresholds developed in the Pacific Northwest are reasonable for use in Utah. Therefore recommendations of action thresholds of 5 moths for 10X and Combo lures and 2 moths for DA lures are suitable. These thresholds are based on a trap density of one trap per 2 to 3 acres and counting and removing moths about once per week.

A disadvantage of the 10X lures is that they are only effective for about three weeks compared to eight weeks for DA and Combo lures. The cost of the lures when purchased in the spring of 2007 was $1.23, $3.81, and $4.08 each for 10X, DA, and Combo lures, respectively. Given that DA and Combo lures last 2.7 times longer than 10X lures, the comparative cost for 10X lures to last eight weeks is $3.32, so the cost savings is only $0.49 to $0.76 (less than $1 per trap for an eight week period).

In summary, after two years of comparing commercial codling moth lures (DA lures were evaluated in only one year), the use of DA and/or Combo lures over 10X lures is recommended. A predictive relationship of an increase of 0.1-0.2% in fruit injury for every moth caught in a DA- or Combo-baited trap was determined and action thresholds of 5 moths for Combo and 2 moths for DA lures was reasonable.

References:

Brunner, J. and L. Gut. 1996. Trap thresholds for codling moth management. Washington State University Cooperative Extension Areawide IPM Update. Vol. 1, No. 4. http://www.tfrec.wsu.edu/IPMnews/IPM501.html#Trap

Knight, A., R. Hilton, P. VanBuskirk, and D. Light. 2006. Using pear ester to monitor codling moth in sex pheromone treated orchards. Oregon State University Extension Publication EM 8904 (8 pp.).

Figure 1. Influence of trap lure on codling moth adult catch in 12 Utah County apple orchards with mating disruption, 2007. N = 36 replicates per lure.

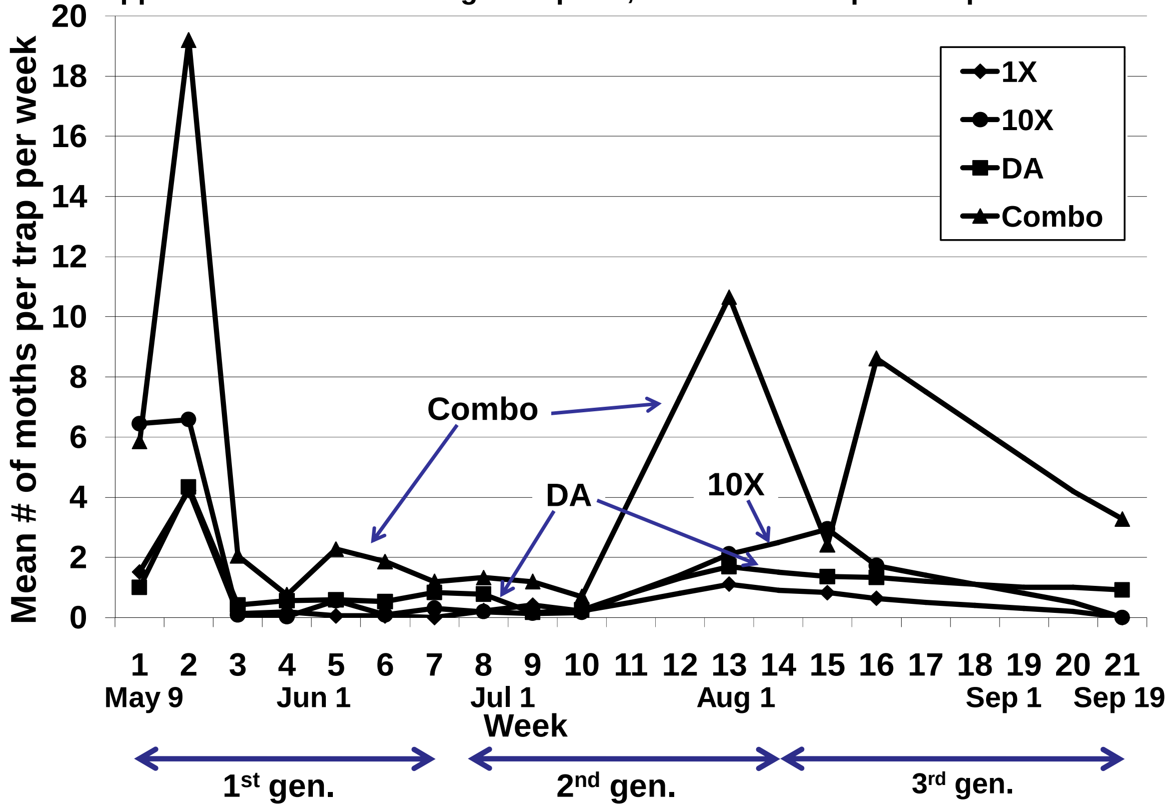


Figure 2A. Grower A. Influence of lure type on trap catch, 2007.

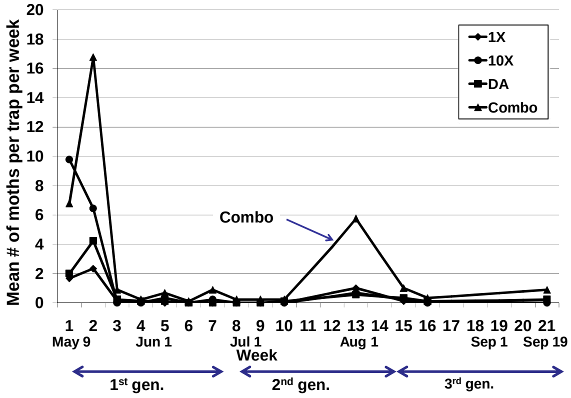


Figure 2B. Grower B. Influence of lure type on trap catch, 2007.

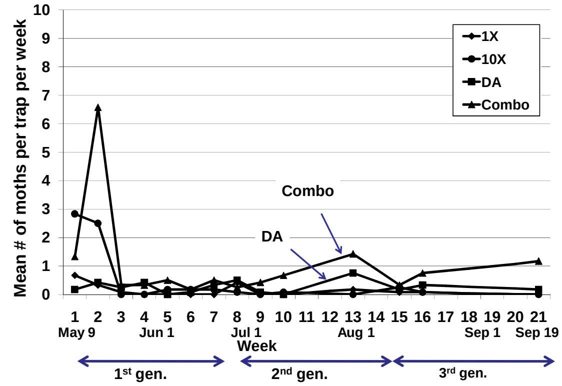


Figure 2C. Grower C. Influence of lure type on trap catch, 2007.

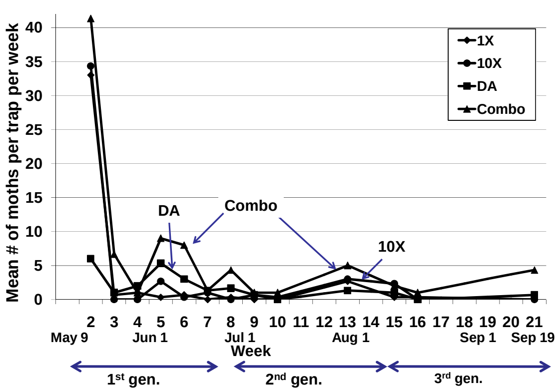


Figure 2D. Grower D. Influence of lure type on trap catch, 2007.

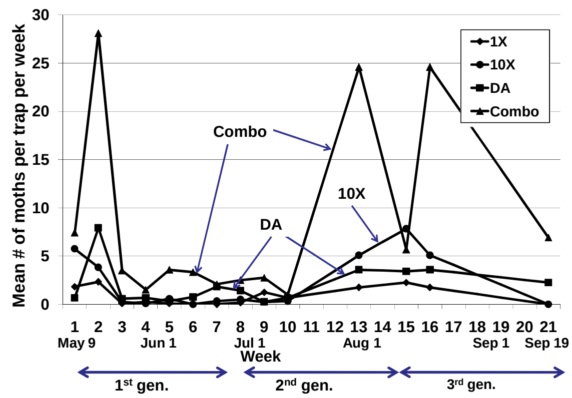
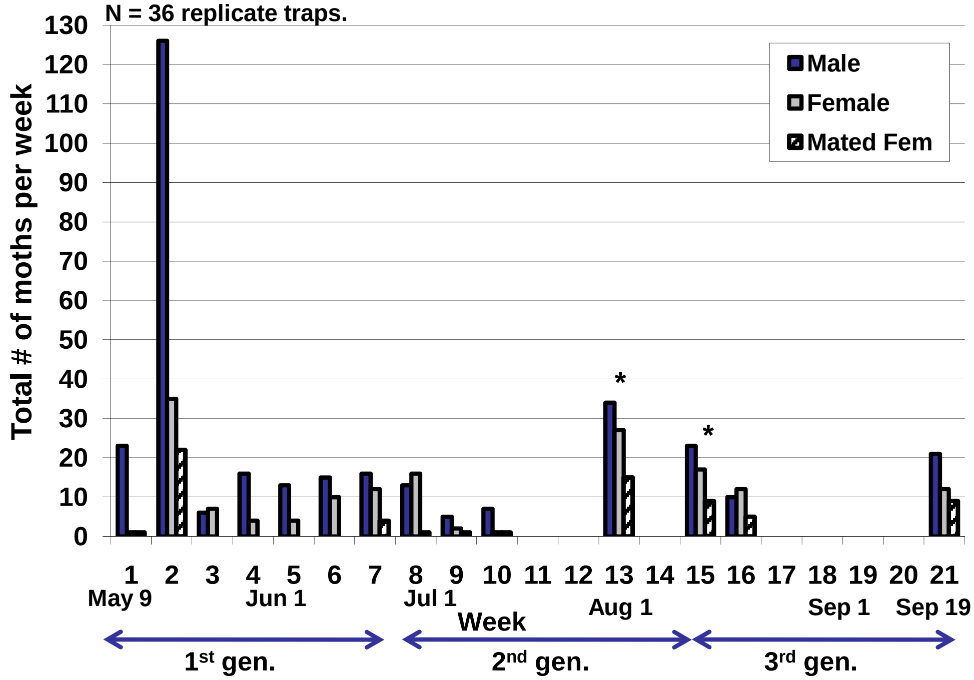
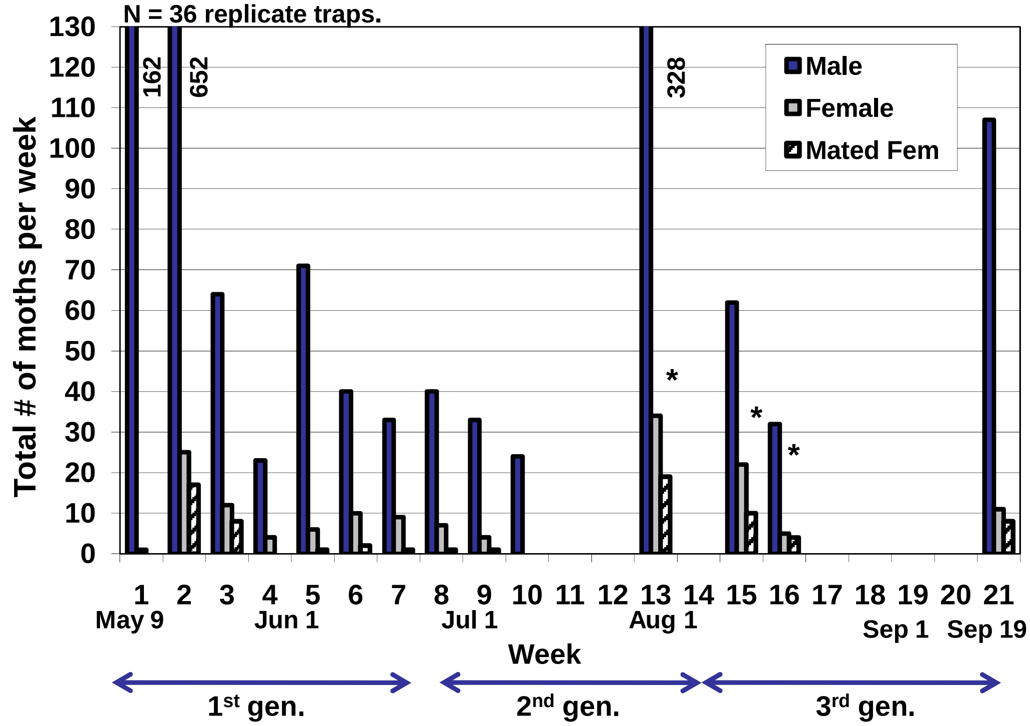


Figure 3. Gender and mating status of codling moth adults caught in DA-baited traps in 12 Utah County apple orchards with mating disruption, 2007. N = 36 replicate traps.



*Dates with females that were mated more than once

Figure 4. Gender and mating status of codling moth adults caught in Combo-baited traps in 12 Utah County apple orchards with mating disruption, 2007. N = 36 replicate traps.



*Dates with females that were mated more than once

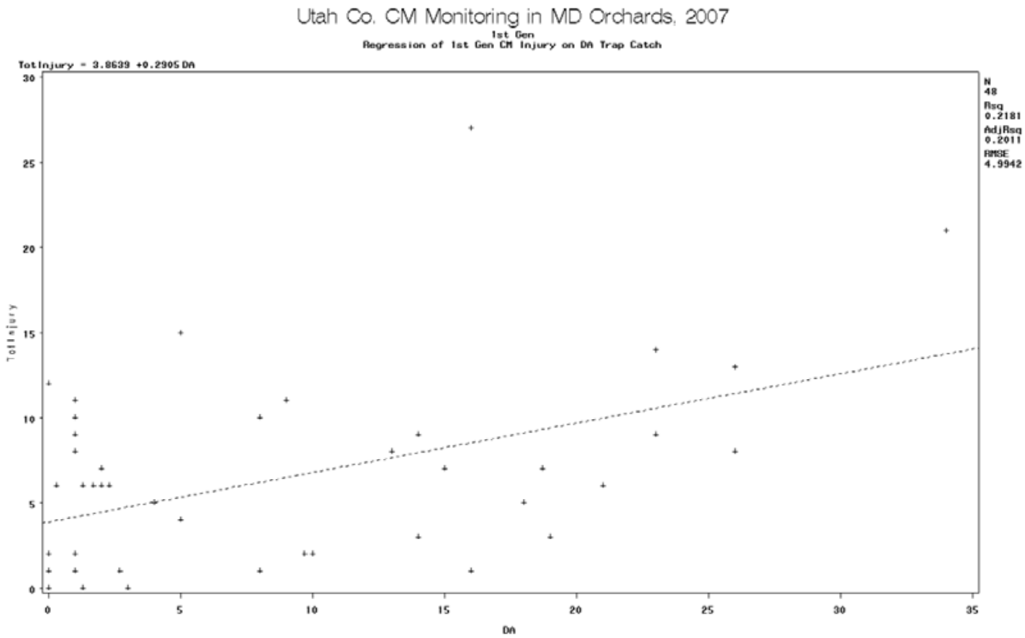


Figure 5. Regression relationship between apple fruit injury and trap catch in DA-baited traps for the first generation of codling moth (p = 0.008, r^2 = 0.22).

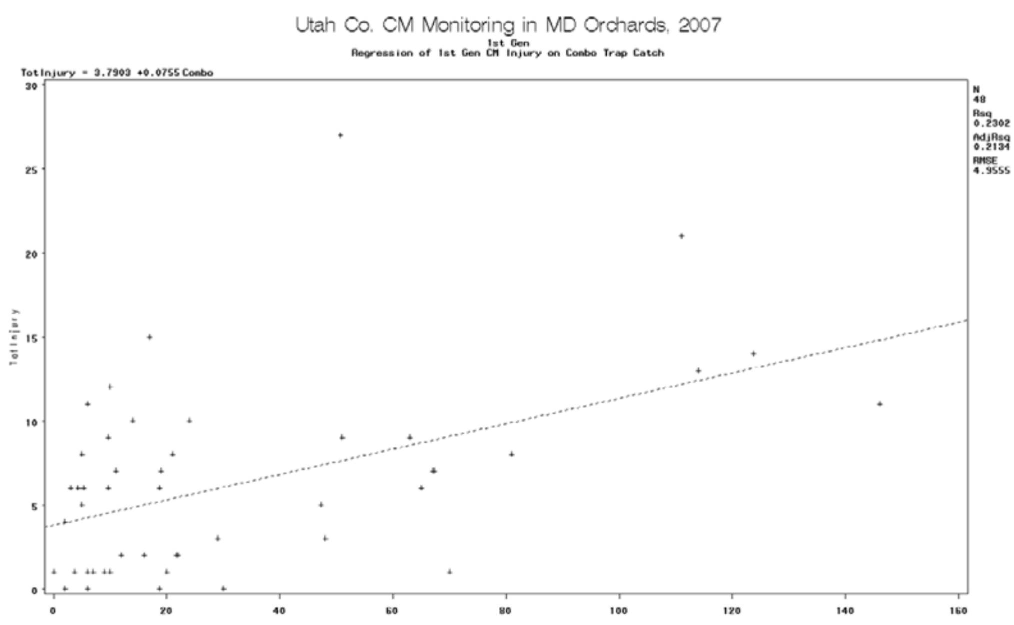


Figure 6. Regression relationship between apple fruit injury and trap catch in Combo-baited traps for the first generation of codling moth (p = 0.006, r^2 = 0.23).

Table 1. Relationship of codling moth trap catch for four pheromone lures (1X, 10X, DA, and Combo) to mean fruit injury (stings and larval entries) in 12 apple orchards, Utah County, 2007. Results are presented for three codling moth generations and the season total.

Grower/ Orchard	Cumulative mean # of codling moths per trap																Mean % of fruit with codling moth injury						
	1st generation*				2nd generation*				3rd generation*				Season total*				1st generation^		2nd generation^		Season total		
	1X	10X	DA	Com-bo	1X	10X	DA	Com-bo	1X	10X	DA	Com-bo	1X	10X	DA	Com-bo	Sting	Entry	Sting	Entry	Sting	Entry	Total
A / Fuji	1.3	4.7	1.7	9.7	0.0	0.3	1.7	9.3	0.0	0.3	1.3	3.3	1.3	5.3	4.7	22.3	8.3	0.0	1.3	0.0	9.5	0.0	9.5
A / Jonathan	6.3	18.3	2.3	18.7	3.0	1.7	0.3	7.2	0.3	0.3	0.3	2.3	9.6	20.3	2.9	28.2	7.5	0.0	1.3	0.3	8.8	0.3	9.0
A / Red Del.	5.0	27.3	16.0	50.7	0.0	0.0	0.0	2.7	0.0	0.0	0.3	1.0	5.0	27.3	16.3	54.4	11.3	0.0	1.5	0.3	12.8	0.3	13.0
B / Fuji	0.0	1.3	1.3	4.3	0.0	0.0	1.7	3.3	0.3	0.7	1.0	2.3	0.3	2.0	4.0	9.9	9.0	0.0	1.5	0.0	10.5	0.0	10.5
B / Gala	1.7	4.7	1.0	9.7	0.3	0.3	0.3	4.7	0.0	0.3	0.3	5.3	2.0	5.3	1.6	19.7	4.5	0.0	1.8	0.3	6.3	0.3	6.5
B / Gala2	1.0	9.3	1.3	18.7	0.3	0.0	1.0	0.7	0.0	0.3	0.0	0.7	1.3	9.6	2.3	20.1	0.8	0.0	1.8	0.0	2.5	0.0	2.5
B / Golden Del.	0.3	2.3	2.7	3.7	1.7	0.3	2.3	2.3	0.3	0.0	1.3	0.7	2.3	2.6	6.3	6.7	5.5	0.0	1.3	0.0	6.8	0.0	6.8
C / Golden Del.	35.7	38.3	18.7	67.3	3.0	4.0	3.7	11.3	0.7	2.3	1.7	7.3	39.4	44.6	24.1	85.9	6.3	0.0	2.5	0.0	8.8	0.0	8.8
D / Cameo	0.3	2.7	0.3	5.3	0.3	0.7	0.3	4.7	0.3	0.7	0.7	4.0	0.9	4.1	1.3	14.0	2.3	0.0	2.5	0.5	4.8	0.5	5.3
D / Gala	12.0	21.7	23.0	123.7	12.3	21.7	12.0	71.3	12.3	41.3	20.0	68.3	36.6	84.7	55.0	263.3	14.3	0.5	3.0	0.5	17.3	1.0	18.3
D / Red Del.	2.7	8.3	9.7	21.7	0.7	1.0	6.7	15.7	0.3	2.0	8.7	26.7	3.7	11.3	25.1	64.1	5.3	0.0	3.0	0.3	8.3	0.3	8.5
D / Red Del.2	3.3	10.7	18.0	47.3	2.0	1.3	4.7	31.7	3.0	7.7	7.7	49.7	8.3	19.7	30.4	128.7	4.3	0.0	0.8	0.0	5.0	0.0	5.0

*First trap catch (biofix) was April 26-29. Traps with test lures were placed in orchards from May 1-9. First generation of codling moth flight ended approximately June 20, second generation flight ended approximately August 3, and third generation flight ended approximately September 15.

^First generation fruit injury was sampled on July 11 and second generation fruit injury was sampled on August 16, 2007.