

FINAL REPORT**DURATION:** 2 years (2007-2008)**Project Title:** Fate of codling moth in apples after harvest

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Cooperators: Michael Willett, NHC**Budget:**

Year 1: \$58,815 **Year 2:** \$55,000 **Total Funding:** \$113,815

Item	Year 1: 2007	Year 2: 2008
Salaries	\$31,312	\$32,250
Benefits	\$9,393	\$9,675
Wages		
Benefits		
Equipment		
Supplies	\$18,110	\$13,075
Travel		
Miscellaneous		
Total	\$58,815	\$55,000

Original Objectives:

The overall objective of this project is to develop information regarding the fate of codling moth in apples destined for export to Asian Pacific countries. The specific objectives were:

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- 1) Determine the critical duration of chilling needed for diapause-destined larvae needed to break diapause.
- 2) Determine the fate of diapause-destined larvae under tropical environments (short photoperiod, elevated temperatures, high chilling temperatures, short chilling period).
- 3) Determine the proportion of field codling moth population entering diapause at each harvest date.
- 4) Determine the proportion of both field and laboratory codling moth diapause-destined larvae surviving cold storage.

Significant Findings:

- 1) During both the first and second years any larvae that were not subjected to a cold storage and did not receive a chilling period of at least 2 weeks at 10°C (50°F), did not emerge as moths when placed at 20°C (68°F) under a 12:12 L:D photoperiod (Figure 1, 0 days @ 33°F).
- 2) For larvae that were cold stored, but did not receive a chilling treatment of at least 2 weeks at 50°F, only 0.5% emerged as moths (Figure 1).
- 3) Of those moths that emerged from the non-chilling group, only 25% emerged within the 6 week window previously used by USDA-APHIS-PERAL in their risk assessment (Figure 2).
- 4) Only 17% of all moths emerging from all treatments in the first year emerged within the 6 week window. Only 34% of all moths emerging from all treatments in the second year emerged within the 6 week window (Figure 2).
- 5) There is only a 0.2% chance that any moths would emerge within the 6 week window stipulated by USDA-APHIS-PERAL. There is nearly a zero percent chance that any larvae resulting from a successful mating would ever be able to complete development and diapause to produce a second generation.

Results and Discussion:

We completed two years of the field experiments of codling moth infested apples over 7 harvest dates. We completed the collection of the second year emergence data in November 2009. We did collect a 3rd year of infested apples, but limited the study to only cold stored fruit and did not store any fruit at 10°C (50°F). We believe that these conditions more closely approximate the tropical conditions most likely to be experienced by any codling moth entering Taiwan. To date, we have not had any emergence in any sample held under the 12:12 L:D photoperiod at 68°F in this third year of samples. We have had significant emergence from samples held at 16:8 L:D photoperiod at 68°F.

There was no moth emergence from any harvest date over the two years from fruit that was not cold stored and did not receive chilling at 68°F of at least 2 weeks. This means that codling moth cannot develop and successfully complete diapause under a 12:12 L:D photoperiod at 68°F.

In fruit that was cold stored, but did not receive a chilling period of at least 2 weeks at 50°F, only 0.5% emerged as moths. In the first year a total of 6 moths emerged from the 864 larvae in the no-chill group. In the second year only 8 moths emerged from the 603 larvae in the no-chill group. Of those, only 25% emerged within the 6 week window previously (Figure 2) stipulated by APHIS in their risk assessment. This gives us an estimated risk of emergence for the zero chill group within the 6 week period of only 0.125%. This is greatly reduced from the 100% previously used by USDA-APHIS-PERAL.

For both years of the study when cardboard strips were examined following 6 months at 68°F 12:12 L:D, the proportion of larvae that remained in diapause for the zero chilling groups was 13.3%, and the number proportion of dead larvae in the strips was 6.3%. It was estimated that only 30% of the collected larvae were ever able to successfully exit the fruit and initiate diapause. This agrees with previous published research that only 30% of a codling moth population could survive from one season to the next. This number was not used in the APHIS model for early and middle season fruit, where they assumed 100% of all larvae entering the country would survive diapause and emerge and moths.

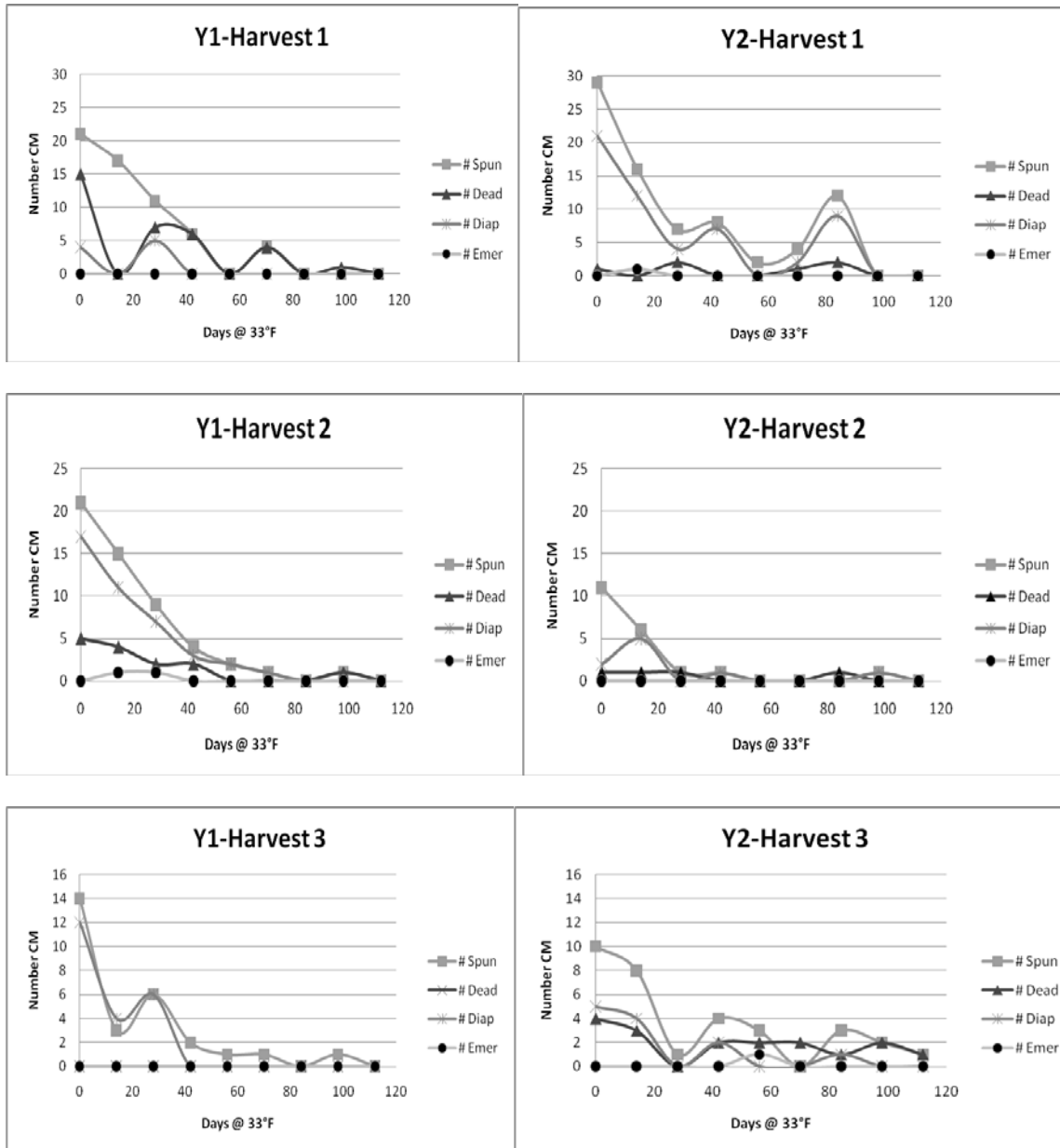
It is interesting to note that when the cardboard strips were examined following the 6 months of storage at 12:12 L:D photoperiod at 68°F, those larvae that were remaining in the strips were approximately 50 to 75% smaller than normally diapausing larvae held under a short photoperiod (8:16 L:D). This indicates that much of the energy reserves, predominately lipids, were utilized during the prolonged state of diapause. Loss of energy reserves would reduce future fecundity and the ability of adults to fly any significant distance. It is also interesting to note that a majority of the moths that emerged were females. This is most likely due to the additional lipid reserves in the ovaries. If lipid reserves were taken from the ovaries during the prolonged diapause period, as is the case for many diapausing insects, then overall fecundity of the females would be greatly reduced.

For the entire first year an estimated total of 8640 larvae were collected and only 125 moths emerged for a total for the entire experiment of 1.4%. For the entire second year an estimated total of 6030 larvae were collected and only 106 moths emerged for a total for the entire experiment of 1.7%. In addition, only 17% of the moths emerging from the first year and only 34% of the moths emerging from the second year emerged within the 6 week window. This brings the proportion of total moths emerging within the 6 week period down to 0.2% for the first year and 0.5% for the second year. These data include storage at 50°F for durations of 2 or more weeks, optimal conditions for meeting the requirement for diapause break. However, exposure of fruit/larvae to temperatures under 50°F for greater than 2 weeks in Taiwan is highly unlikely.

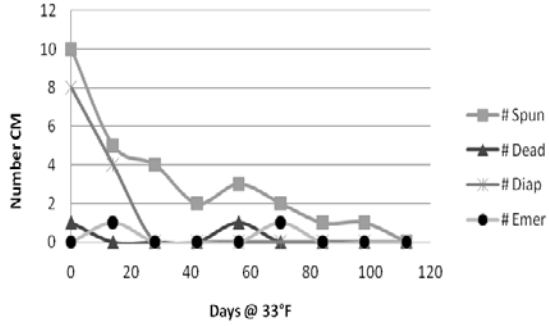
In studies with laboratory colony insects on thinning apples, no moths emerged from any larvae that successfully cocooned when reared under a 12:12 L:D photoperiod at 68°C with no cold storage or chilling. However, very few larvae successfully exited the thinning apples to reach cocooning strips, making this series of experiments difficult to analyze.

It is my understanding that USDA-APHIS-PERAL intends to publish their risk assessment of the potential of codling moth establishment in Taiwan this year. I will contact Dr. Robert Griffin director of the Plant Epidemiology and Risk Analysis Laboratory and provide his group with these new data so that they can re-assess the risk and incorporate those changes into a revised manuscript. In addition, we will complete our collection of data for the 3rd year in August 2010. When these data are complete and analyzed, a manuscript will be prepared for a peer reviewed scientific journal, most likely the Journal of Economic Entomology.

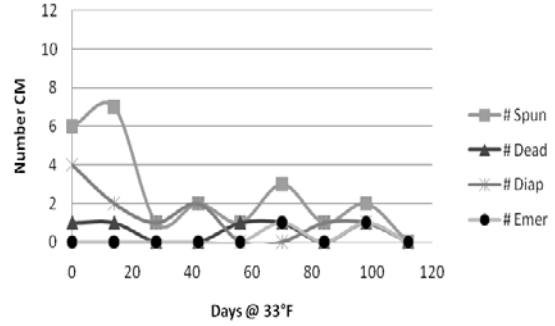
Figure 1. Comparison of years 1 & 2 moth emergence from codling moth infested apples stored at 33°F for 0 to 112 days then placed at 68°F under a 12:12 L:D photoperiod for up to 6 months.



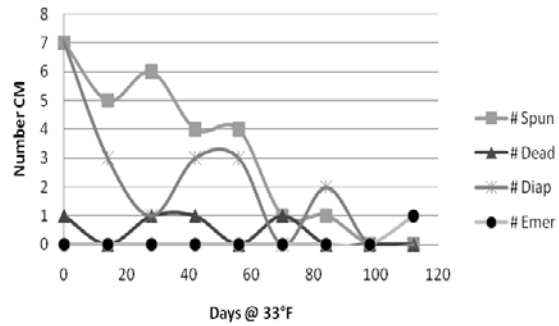
Y1-Harvest 4



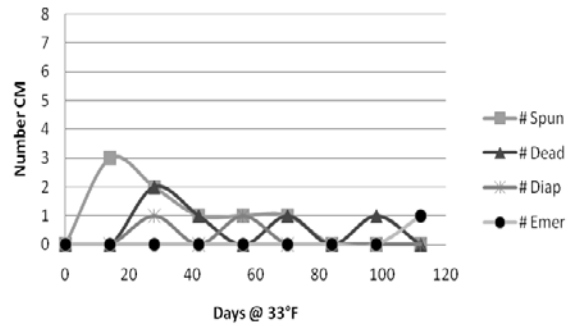
Y2-Harvest 4



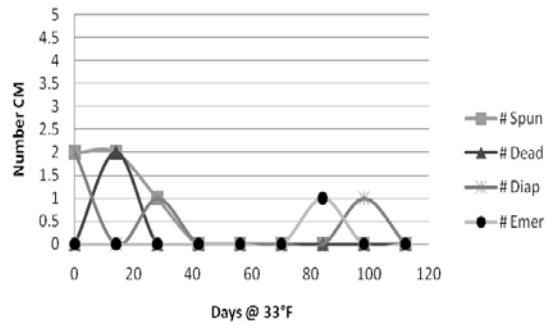
Y1-Harvest 5



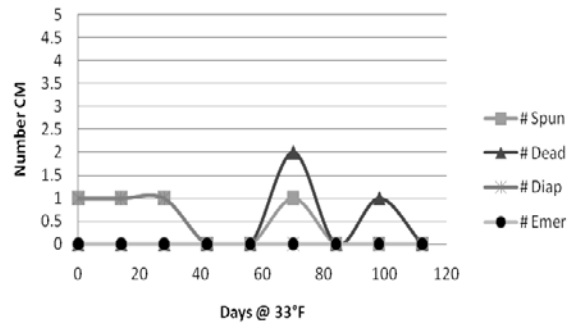
Y2-Harvest 5



Y1-Harvest 6



Y2-Harvest 6



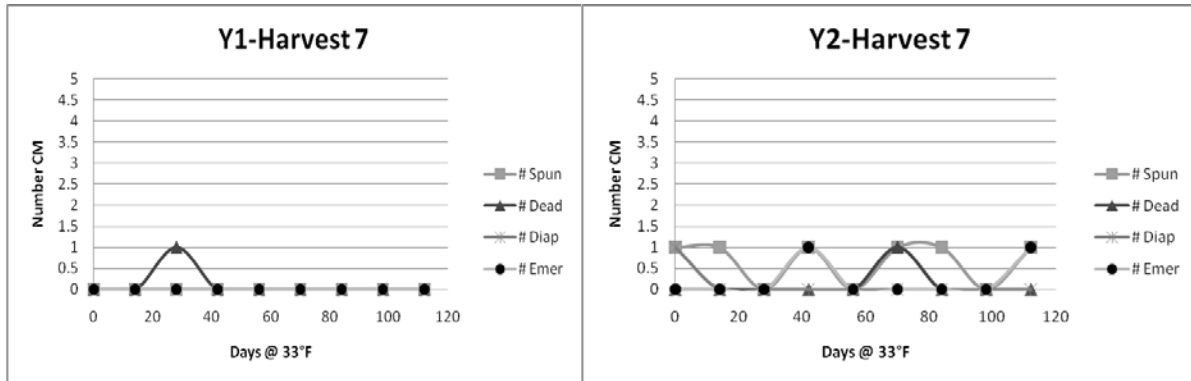
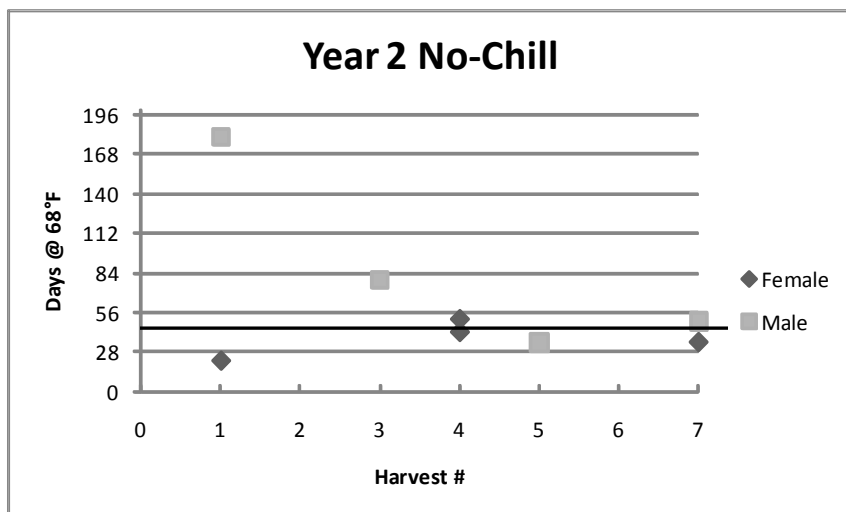
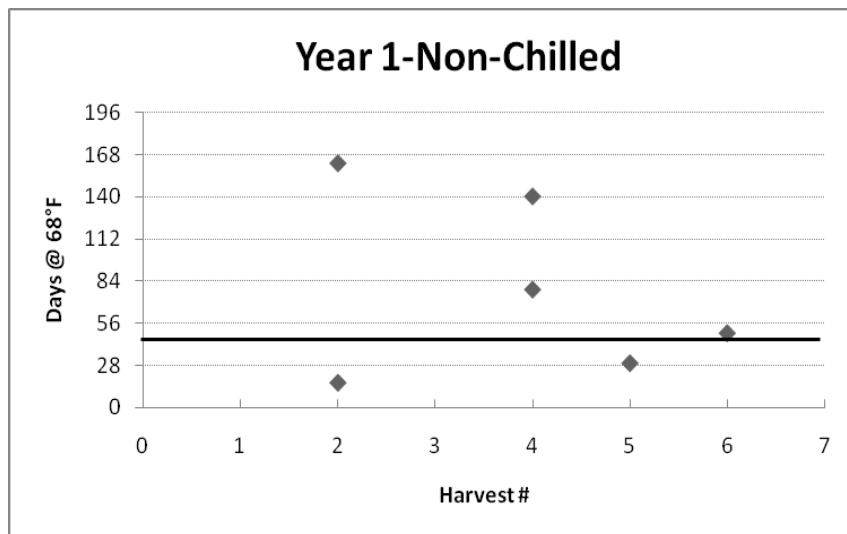


Figure 2. Days to emergence of codling moths from infested apples stored at 33°F for 0 to 112 days then placed at 68°F under a 12:12 L:D photoperiod for up to 6 months. Moths above the solid black line did not emerge within the 6 week window previously used by USDA-APHIS-PERAL in their risk assessment.



Executive Summary:

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The risk assessment performed by USDA-APHIS-PERAL manipulated the existing published data on codling moth presence in packed fruit, overall survivorship, and post-diapause emergence (not under tropical conditions). With this new information, we can provide USDA-APHIS-PERAL with new data that accurately describes the ability of codling moth to complete diapause and emerge under tropical conditions (i.e. photoperiods of 12:12 L:D) with no chilling at temperatures at or below 10°C (50°F). In the original assessment, they predicted that 100% of all larvae arriving in infested apples would successfully survive, complete diapause, and emerge as moths within a 6 week period. We now know that it is highly unlikely that any codling moths will be able to complete diapause and emerge as moths within this 6 week window. There is only a 0.125% chance that any moths from fruit that had been cold stored for any duration would emerge as moths. Taking the field and laboratory tests into account, it is highly unlikely that any progeny from a highly unlikely mating pair would ever complete diapause and emerge as moths. We will provide USDA-APHIS-PERAL with a report of the results of this study so that they can reassess the risk of codling moth establishment in Taiwan.