FINAL REPORT **DURATION**: 2 years (2007-2008)

Project Title: Fate of codling moth in apples after harvest

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Total funding request: $113,515

Other funding sources: None

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:

Objectives:
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) With only one year of data, it is difficult to determine the critical chilling period needed to break diapause for each harvest date. It was observed that emergence took longer with shorter cold storage durations (Figures 1) and cool storage durations less than 1 month (Figure 2).
2) For the most part, larvae either died or remained in diapause when maintained on a 12:12 L:D photoperiod at 68F (Figure 3). Very few moths emerged under these conditions. We did notice a peak of emergence in the 5th harvest, most likely due to the presence of a 3rd generation of codling moth.
3) The proportion of larvae entering diapause for the first harvest was very low, and few survived cold and cool storage. Approximately half of the larvae in the second harvest (August 15) were diapause destined since only half survived cold storage for more than 2 months. By the 3rd harvest most of the larvae were diapause destined and easily survived cold storage for more than 2 months.
4) Although cold storage did kill a majority of the larvae in the first and second harvest within the first 8 weeks of storage, we still observed cocooning or moth emergence after more than 14 weeks of cold storage. After the 3rd harvest, cold storage had a less pronounced effect on mortality. Many of the moths emerged following more than 3 months of cold storage.

Results and Discussion:
We did notice trends in harvest date on diapause, survival after cold storage, and the effects of cool storage on moth emergence. As the number of days at 34°F storage increased there was a decrease in the span and duration of moth emergence (Figure 1). As the number of days at 50°F cool storage increased there was an overall decrease in the span and number of days to emergence up to 35 days of storage, after which, there was little change in number of days to emergence (Figure 2).

There was an overall decline in the number of cocooned larvae as harvest progressed through the season (Figure 3). For harvests 1-4 the number of dead and diapaused exceeded to total number of emerged moths (Figure 3). Harvest 5 had more moths emerged than died in the strips, but the number of moths was still less than the number of diapausing larvae (Figure 3). Harvest 6 was the only harvest in which the number of moths exceeded the number of dead or diapausing cocooned larvae (Figure 3). This was most likely due to a significant third flight on codling moths in September.

Harvest 1 (Figure 4) had only 2 moths emerge (sample numbers 10405 and 10409) which correlate to 6 wks @ 34°F and 4 or 8 wks @ 10°C, respectively. This represented a 0.67% emergence of the total number on insects in the harvest.

Harvest 2 (Figure 5) had a number of moths emerge over a span of cold and cool storage regimes. However, only 1 moth emerged for any given sample, and represented only 3.7% of the total number of insects in the harvest.

Harvest 3 (Figure 6) had single moths emerge from a range of cold and cool storage treatments, with emergence from samples held at 34°F for over 16 wk. Total moth emergence was only 8% of the total number of insects in the harvest.

Harvest 4 (Figure 7) had samples with multiple moths emerging from individual treatments, with as many as 4 in one sample (40110), which was not held at 34°F, but spent 9 wk at 50°F. Longer durations of cold storage resulted in less moths emerging from samples. The total number of moths emerging from this harvest was 13.8 of the total number of insects in the harvest.

Harvest 5 (Figure 8) had the highest number and proportion of moths emerging than any other harvest. There were numerous samples having more than 2 moths emerging with a ratio of moths emerging representing 33.3% of the total number of insects in the sample. Moths emerged from the longest duration of cold storage (16 wk) and the shortest duration of cool storage (0 wk).

Harvest 6 (Figure 9) had 52% of the total insects emerge as moths, with 4 samples having 2 moths and 1 sample with 3 moths.

Harvest 7 (Figure 10) had 60% of the total insects emerge as moths. However, there were very few insects in the total harvest (10 total).

These results indicate that a third flight of codling moth holds the greatest risk of codling moth surviving in the fruit than in cooler years when the 3rd flight is either curtailed or eliminated. Contrary to popular belief, larvae in early harvested apples, harvests between August and mid-September, do not hold a greater risk of codling moth survival under tropical conditions (12:12 L:D, 68°F).

Laboratory Colony Research:
We have completed infesting and treating the first series of laboratory colony studies. These conditions involved oviposition under 12:12 L:D, 68°F conditions. The samples are currently in the 6 month holding conditions to monitor for moth emergence (12:12 L:D, 68°F). We will begin the second series of oviposition at 9:15 L:D, 68°F in January 2009.

2008 Harvest Results:
We made 7 harvests of codling moth infested fruits in the Yakima and Douglas counties in the fall of 2008. To date, we have only had 1 moth emerge from any of the harvests. This moth was from harvest 4 and received only 5 wk at 50°F cool treatment before being placed in the emergence room (12:12 L:D, 68°F). The data from this harvest will not be complete until November 2009.

Figure 1. Effects of cold storage at 34°F on length to emergence of codling moth.

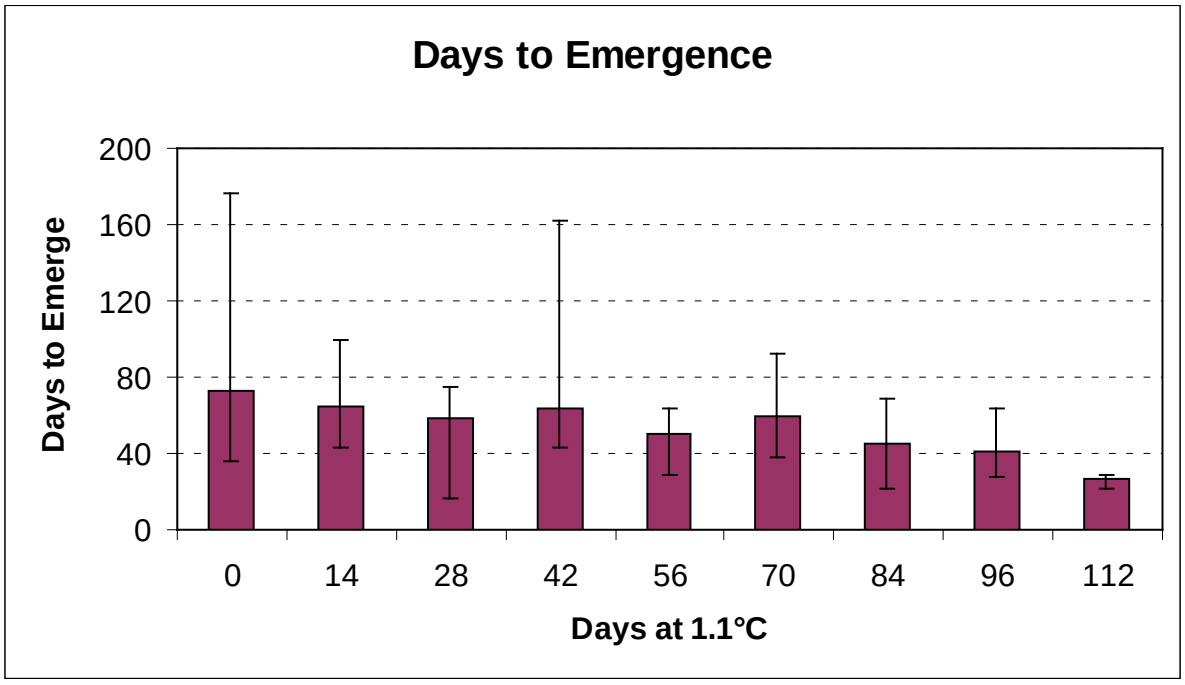

Figure 2. Effects of cool storage at 50°F on length of emergence of codling moth.

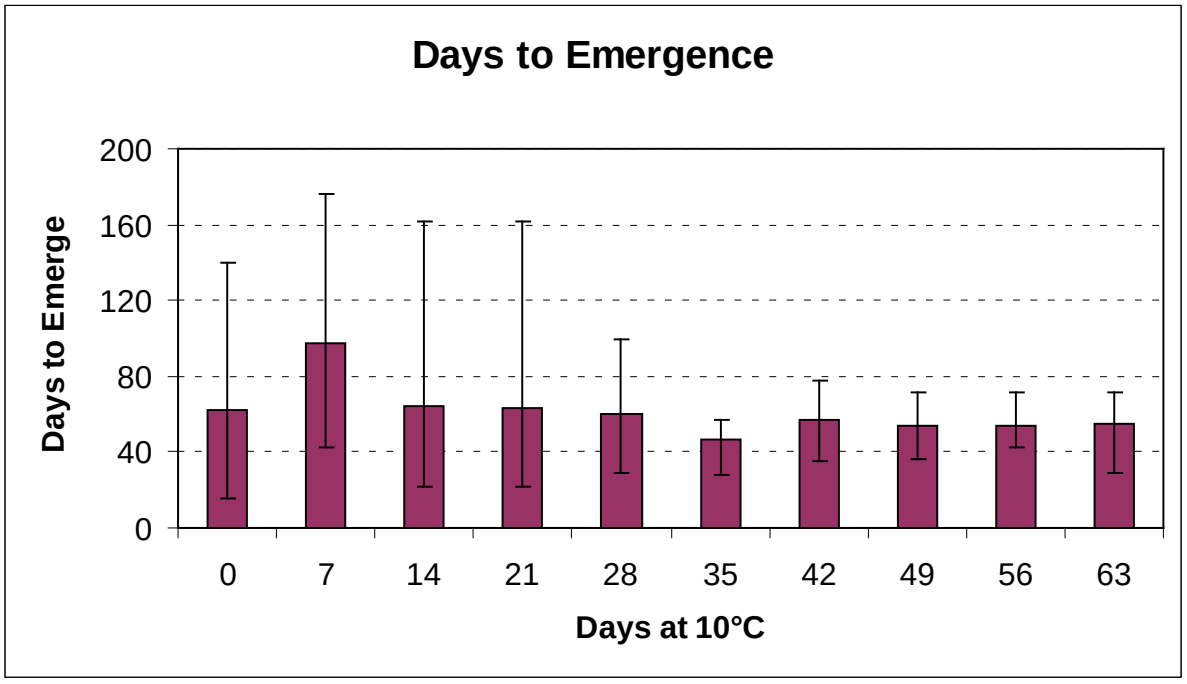

Figure 3. Total number of individual codling moths entering into cocoons (# spun) during weekly evaluations of strips. Total number moths emerging during weekly evaluatons (# Emer). Total number codling moths dead (# Dead) or still in diapause (# Diap) at the final 6 month evaluation.

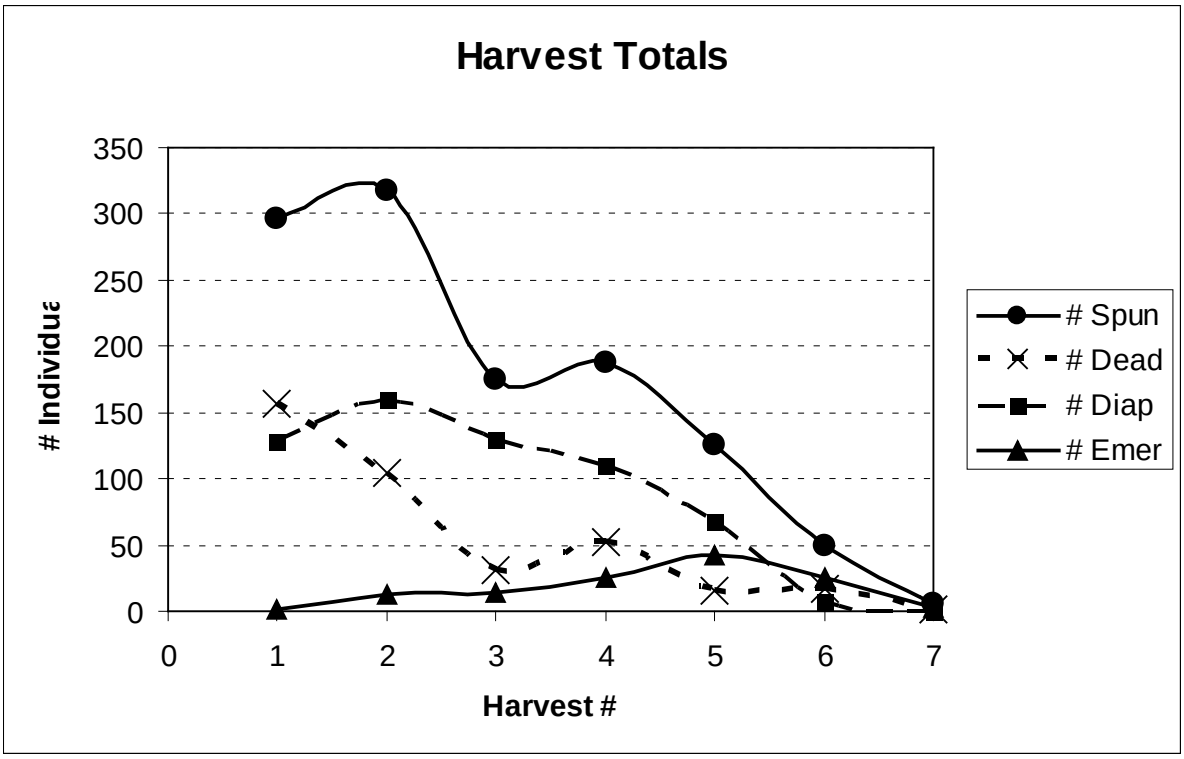

Table 1. A key to the samples numbers.

Number	Condition	Duration	# weeks
1st 2 digits	Harvest Number	1 through 7 at 2 wk intervals	
3rd digit	Weeks at 34F	1 through 9 at 2 wk intervals	0-16 wk
3rd & 4th digit	Weeks at 50F	1 through 10 at 1 wk intervals	0-9 wk

Figure 4. Results from harvest 1 (August 1, 2007).

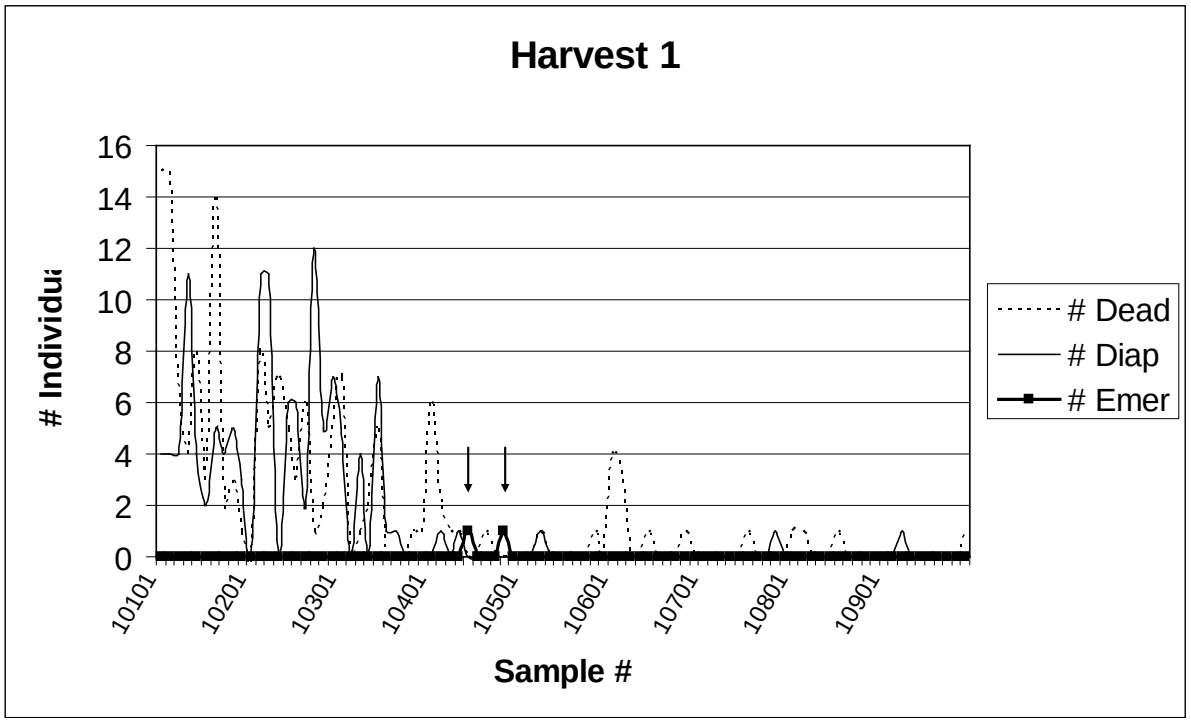

Figure 5. Results from Harvest 2 (August 15, 2007).

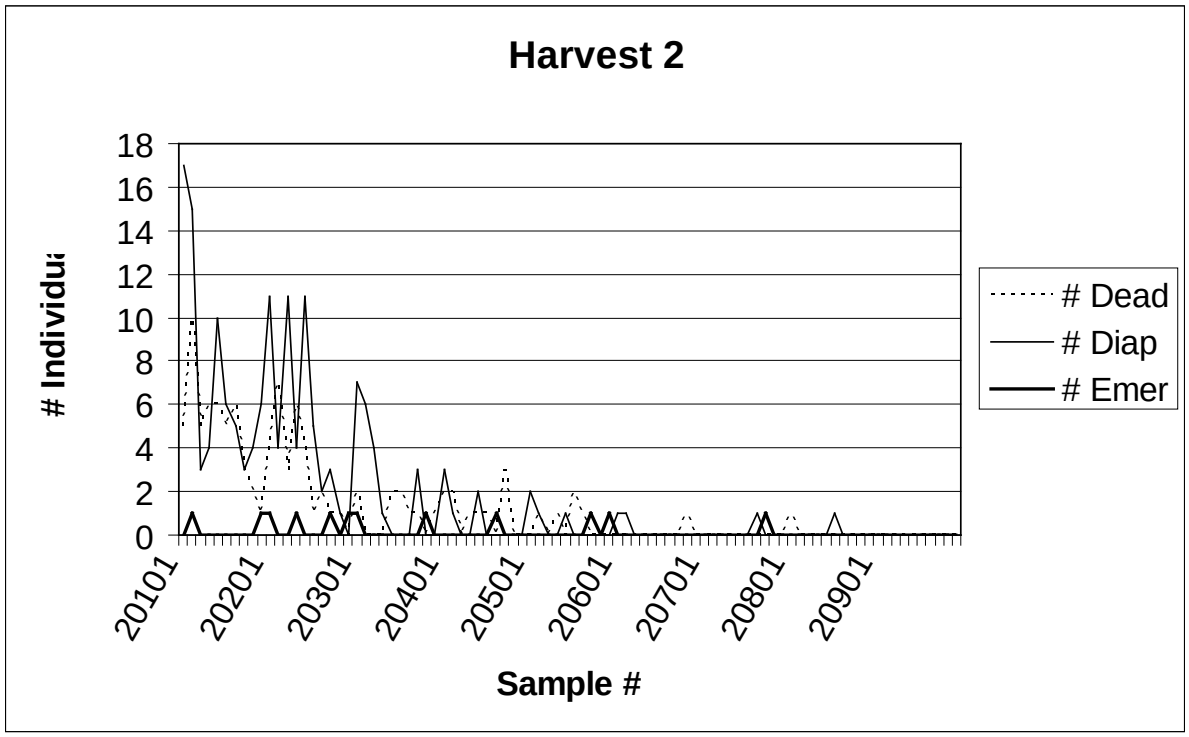

Figure 6. Results Harvest 3 (August 29, 2007).

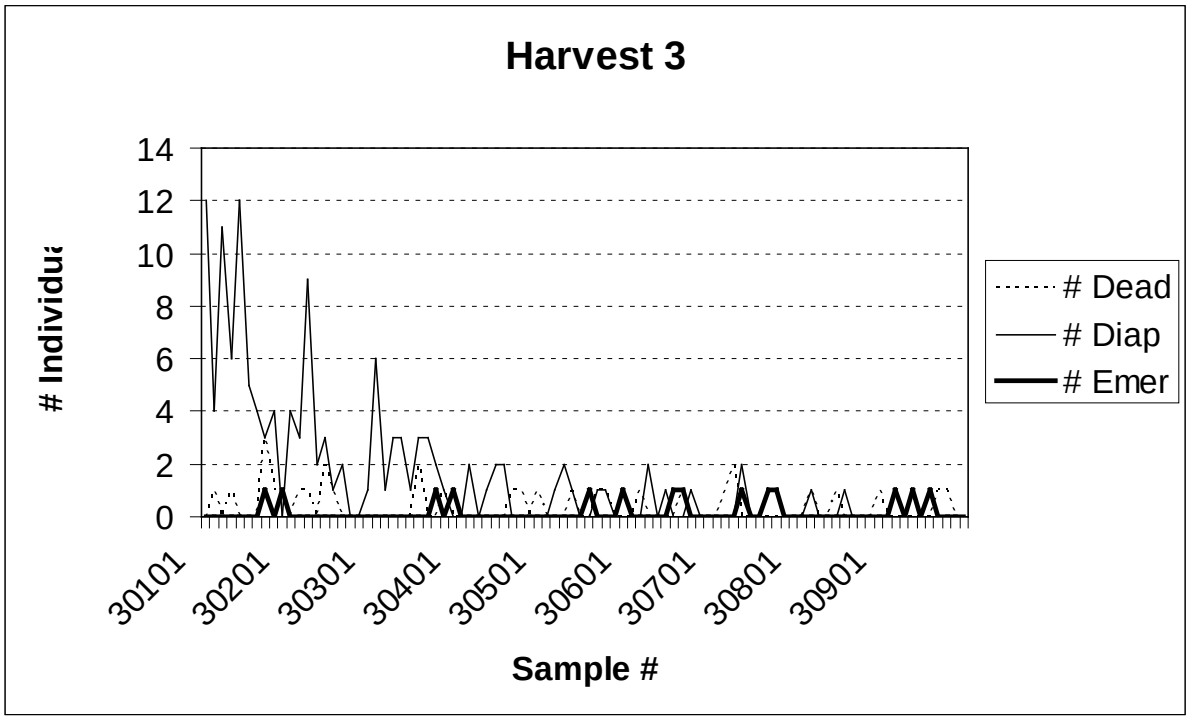

Figure 7. Results of Harvest 4 (September 12, 2007).

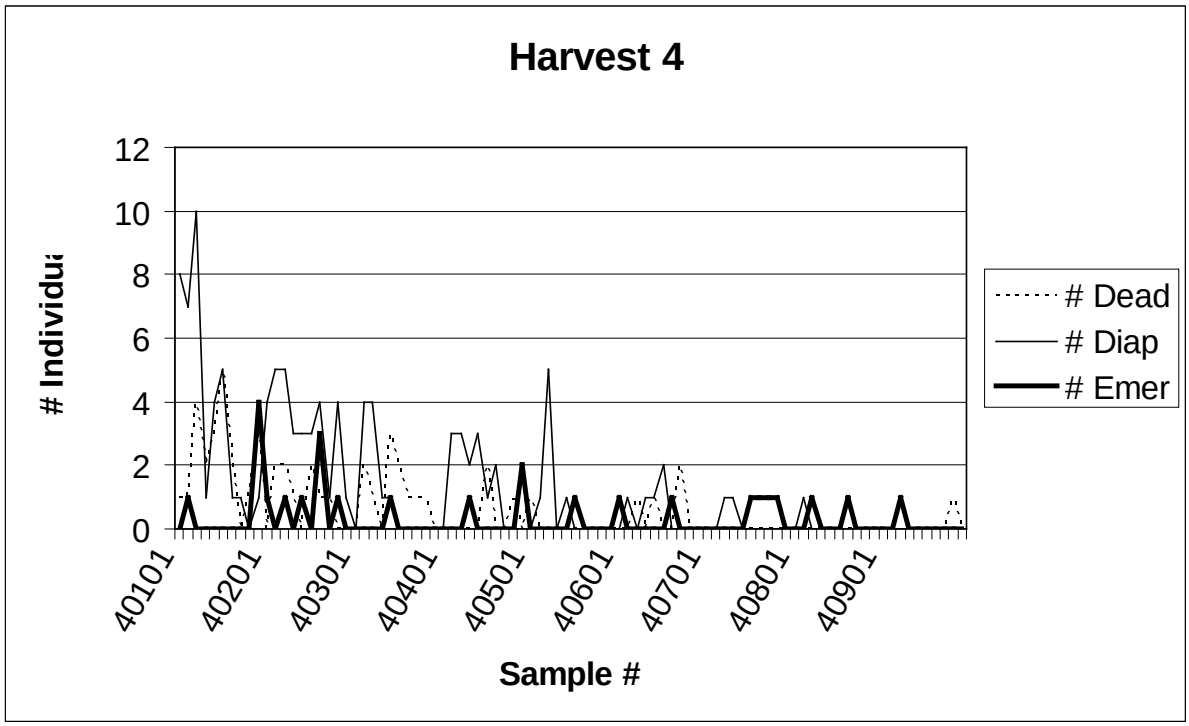

Figure 8. Results of Harvest 5 (September 26, 2007).

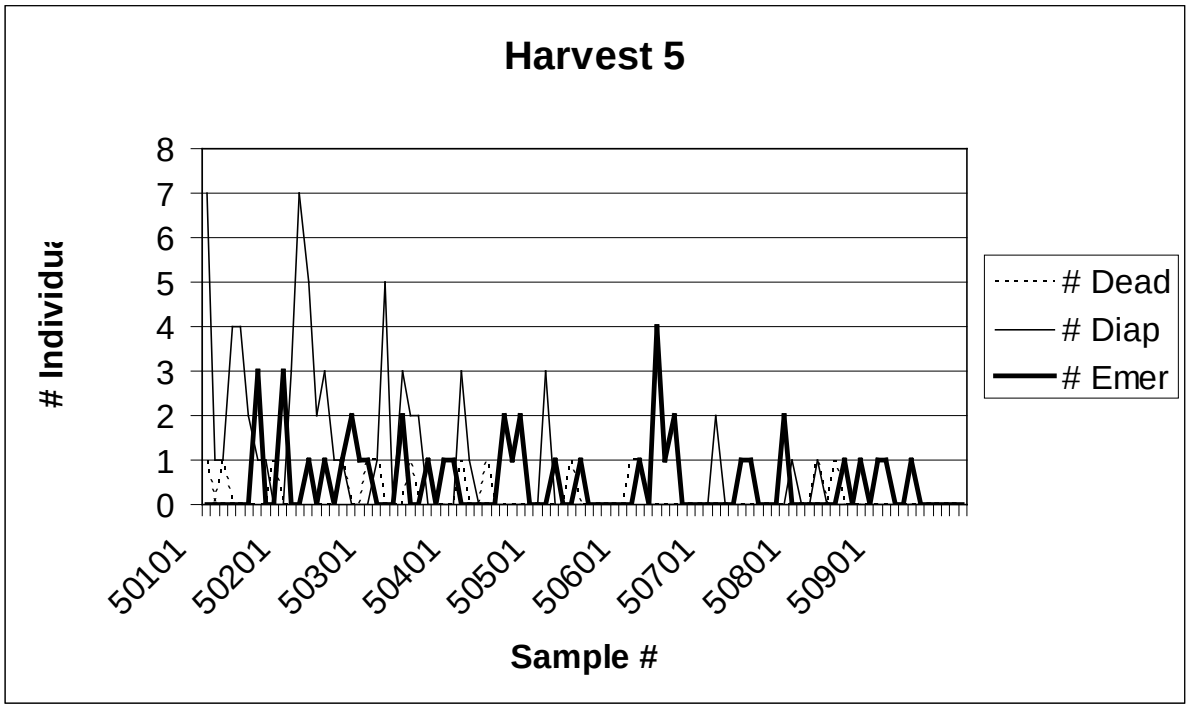

Figure 9. Results of Harvest 6 (October 10, 2007).

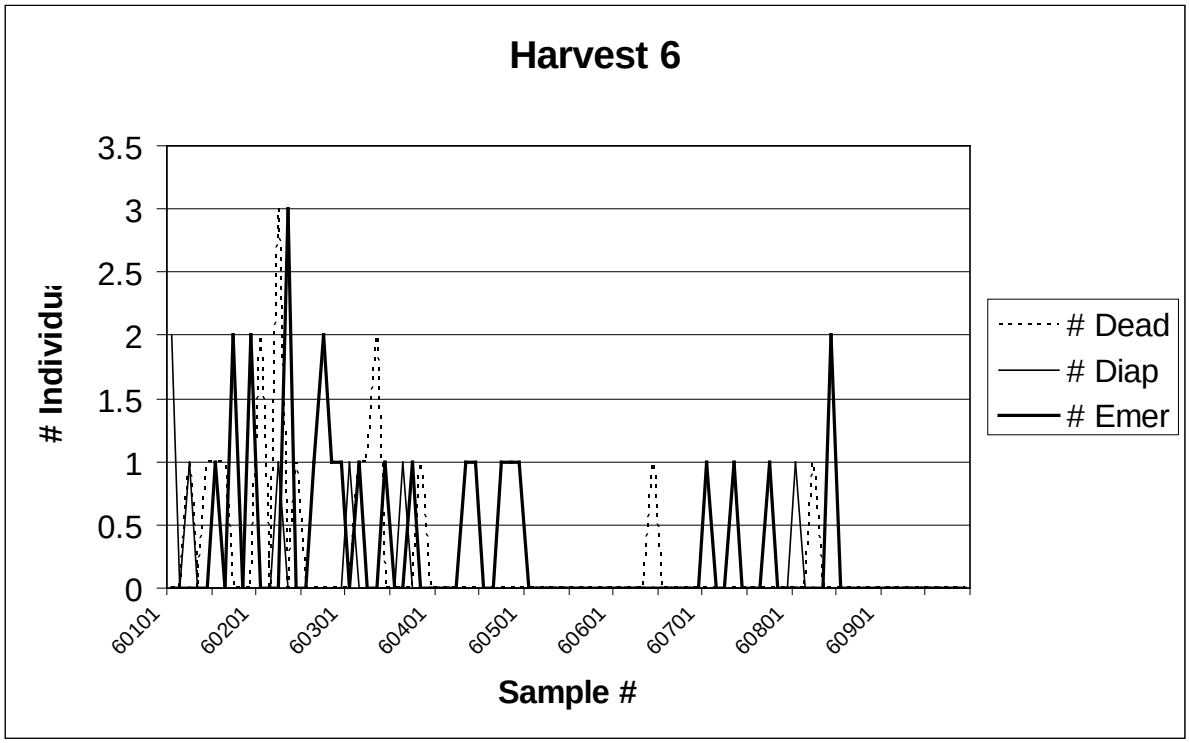

Figure 10. Results from Harvest 7 (October 24, 2007).

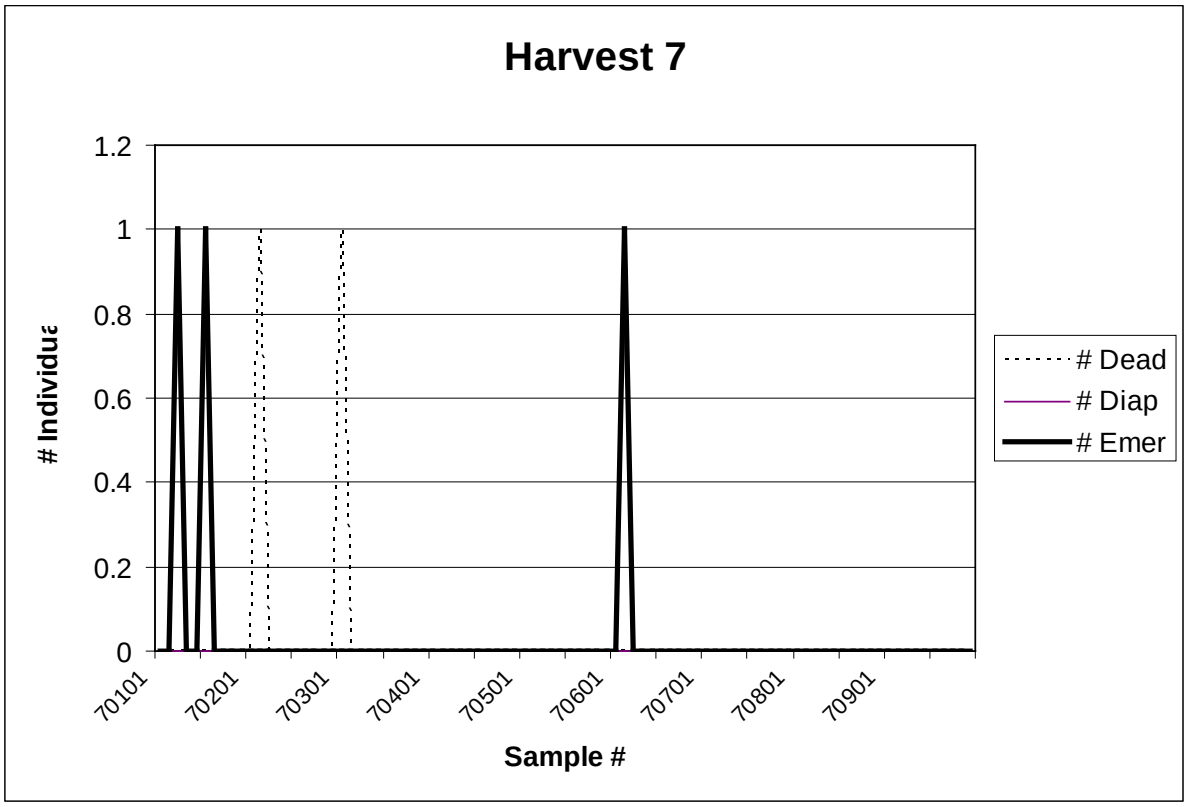

Table 2. Percentage of codling moth in diapause, dead or emerged from each harvest.

Harvest	Date	% Diapause	% Dead	% Emerged
1	August 1, 2007	43.4	52.9	0.06
2	August 15, 2007	50.8	32.8	3.8
3	August 29, 2007	74.3	17.7	8.0
4	September 12, 2008	58.5	27.7	13.8
5	September 26, 2007	54.0	12.7	33.3
6	October 10, 2007	14.0	34.0	52.0
7*	October 24, 2007	0.0	40.0	60.0

* Only a total of 5 codling moth in harvest.

Executive Summary

Project Title: Fate of codling moth in apples after harvest

Codling moth in apples destined for foreign ports in tropical climates poses a threat to maintaining these export markets. The primary threat being that we do not have accurate numbers on the probability of these moths to survive commercial handling procedures and then to survive to emergence as moths under tropical conditions. Data from one year of the study indicates that most of the larvae either die or remain in diapause when held at tropical conditions (12:12 L:D, 68°F). When chilling temperatures are added, it does reduce the time for moth emergence up to 1 month of temperatures at 50°F, but make little difference thereafter.

USDA-APHIS-PERL used emergence durations of 6 weeks. Our data indicate that it can take nearly 180 days for moth to emerge from diapause if they do not receive any cold or chilling treatments. This may greatly affect how the risk model is calculated. In addition, we have estimates of the percentages of larvae in the fruit entering diapause, completing diapause, and emerging as moths for one season. The data from Harvest 7 appears to be quite damaging to our case, but it is based on only 5 larvae in the total harvest. Only 3 moths emerged from the whole harvest.

It is apparent that additional data are needed to accurately determine the risk of codling moth in apples destined to tropical countries. It would be erroneous to base an entire export program on only 1 or 2 years of data where the occurrence of the 3rd flight may completely change the risk calculations.