CONTINUING PROJECT REPORT
WTFRC Project Number: PR07-701 (WSU Project #13L-3643-5431)

Project Title: Using degree-days for timing of pear psylla controls

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Cooperators:

Total project funding: **Year 1:** $31,300 **Year 2:** $31,300

Other Funding Sources

Agency: NONE

WTFRC Collaborative Expenses: NONE

Budget History:

Item	Year 1: 2007	Year 2: 2008
Salaries[1]	18,500	18,500
Benefits (38%)	6,660	6,660
Wages[2]	4,000	4,000
Benefits (11.5%)	460	460
Supplies[3]	900	900
Travel[4]	780	780
Total	31,300	31,300

[1] A portion of the salary for Agricultural Research Technologist position.
[2] Time-slip wages.
[3] Supplies: items including cages, screening, sewing services, Tanglefoot, beating trays, opti-visors. Cell phone charges are allowed under this grant.
[4] Travel: local travel to research plots only.

Recap of Objectives:

1. **Develop a temperature-based model for pear psylla development.**
   a. Develop rates and lower thresholds for development of pear psylla eggs and nymphs in the laboratory and calculate a development model.
   b. Obtain observations of development of pear psylla eggs and nymphs in controlled field locations.
2. **Validate the degree-day model and determine the appropriateness for timing applications throughout the growing season.**
   a. Collect field life stage distribution data over time and compare with predictions of the pear psylla development model.

Significant Findings:

- Developmental rates of pear psylla eggs under controlled temperatures were determined. Egg development threshold was determined to be 4.81^{o}C (40.65^{o}F)
- Developmental threshold for pear psylla nymphs under controlled temperatures were determined. Nymph development threshold was determined to be 4.92^{o}C (40.85^{o}F)
- Development of pear psylla eggs and nymphal instars were measured in the field.
- More investigation is needed in validating the development model, as preliminary model predictions may underestimate the development of observed in the field. This may be dependent on pear psylla densities present.
- No further funding is being requested, however, the model development continue through 2009.

Methods:

To determine developmental rates of pear psylla eggs, adult pear psylla were collected from a pear orchard located at Smith Tract, WSU-TFREC, near Orondo, Washington on May 22, 2007. Adults were collected by beating tray and aspirator and transported to the laboratory. Adults were then exposed to CO2 to immobilize and separate them by sex. Four separate cages containing pear shoots were then loaded with approximately 200 females each and oviposition was allowed for sixteen hours. Shoots were then removed from the cages and the numbers of eggs laid on the shoots were determined. Of those laid in each cage, 98-107 eggs were identified on the leaves and shoot bark and circled with a marking pen. Shoots were then placed in temperature-controlled chambers at 10, 15, 20, and 25^{o}C. Eggs were then checked daily, and the number hatched each day recorded. Nymphs were removed after counting. The eggs were monitored for 30 days.

To determine developmental rates of pear psylla nymphs, adult pear psylla were collected from a pear orchard located at Smith Tract, WSU-TFREC, near Orondo, Washington on May 7, 2008. Adults were collected by beating tray and aspirator and transported to the laboratory. Adults were then exposed to CO2 to immobilize and separate them by sex. Four separate cages containing pear shoots were then loaded with approximately 200 females each and oviposition was allowed for sixteen hours. Shoots remained in the cages and daily observation of hatching was made. Hatched nymphs were circled on the leaf with a permanent marker, and shoots were then placed in temperature-controlled chambers maintained at 10, 15, 20, or 25^{o}C. Nymphs were then checked daily, and the number of days recorded for progression into each nymphal instar was recorded. Shoots were monitored for 30 days, or until the shoot or leaf degraded substantially.

Regression analysis was performed on the rate of eggs hatching and nymphal development at the four temperatures. The resulting regression model was then used to estimate the temperature threshold for egg development, where the rate of development is equal to zero (the x-intercept).

Pear psylla populations were sampled weekly from four pear orchards in the Wenatchee Valley (Wenatchee, Orondo, Monitor, and Dryden) in 2007, five in 2008 (Peshastin was included). Adult pear psylla densities were sampled by beating tray, while nymph and egg densities were sampled by collecting leaves then dislodging the insects onto glass plates using a leaf-brushing machine. Eggs and nymphs were then counted and developmental stage noted by examination under a dissecting microscope.

Additionally, individual eggs were identified and marked on foliage in a pear orchard at WSU-TFREC. Leaves, or areas of leaves, were identified that were free of pear psylla eggs and nymphs and then labeled using a marking pen. Oviposition was then noted on subsequent days, and individual eggs marked for monitoring. Daily observations of the status of the eggs were made. Observations were also made of nymphs following eclosion; however, the movement of the insects, further oviposition, and weather made these data of little utility.

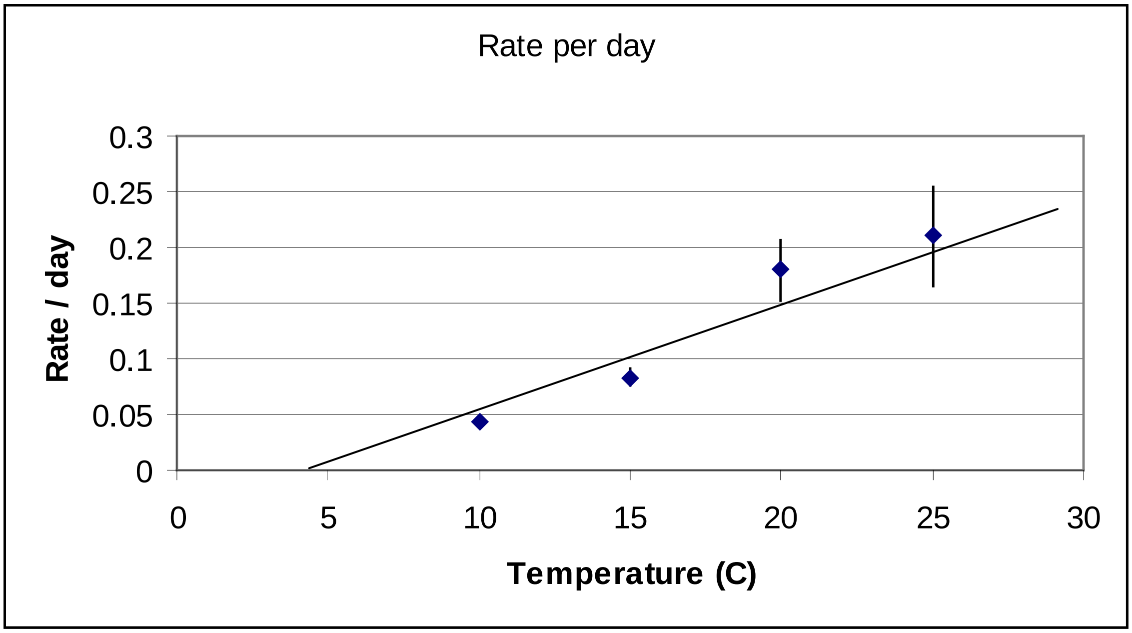
Results and Discussion:

Pear psylla egg developmental rate demonstrated a linear relationship among the four constant temperatures examined (Table 1, Figure 1). There was variation in mortality among the four temperature treatments, in that egg mortality was lowest at 25^{o}C (survivorship at 10, 15, 20, and 25^{o}C: 77%, 70%, 87%, and 95%, respectively). The linear model was a good fit for the data ($p < 0.0001$), and regression coefficient was also significant ($r^2 = 0.705$).

Table 1. Mean developmental rates of pear psylla eggs maintained at constant temperature.

Temperature (^{o}C)	Developmental Rate / Day	Standard Deviation
10	0.043921	0.004208
15	0.083426	0.006846
20	0.180136	0.027039
25	0.21	0.043995

Figure 1. Mean developmental rate of pear psylla eggs (±SD) and the linear regression of rate on temperature treatment.



y=0.0122·T - 0.0589, where y is developmental rate and T is temperature.

Using the regression model, the temperature threshold for egg development of *Cacopsylla pyricola* was estimated to be 4.81°C (40.65°F). This is again slightly higher than the estimates for *Cacopsylla pyri* of 3.46°C (38.22°F) from Schaub et al. (2005) and 3.70 ° C (38.66°F) from Sonnemaison and Missionier (1956; calculated in Schaub et al. 2005). The effects of these slight differences (sensitivity) in temperature thresholds can be seen in Table 2, where 2007 weather data from Wenatchee TFREC were used in a hypothetical single sine phenology model to estimate degree days from January 1 to May 1, 2007.

Table 2. Estimates of degree day accumulations from January 1 to May 1, 2007, at WSU-TFREC, using three different estimates of lower temperature thresholds in a single sine model.

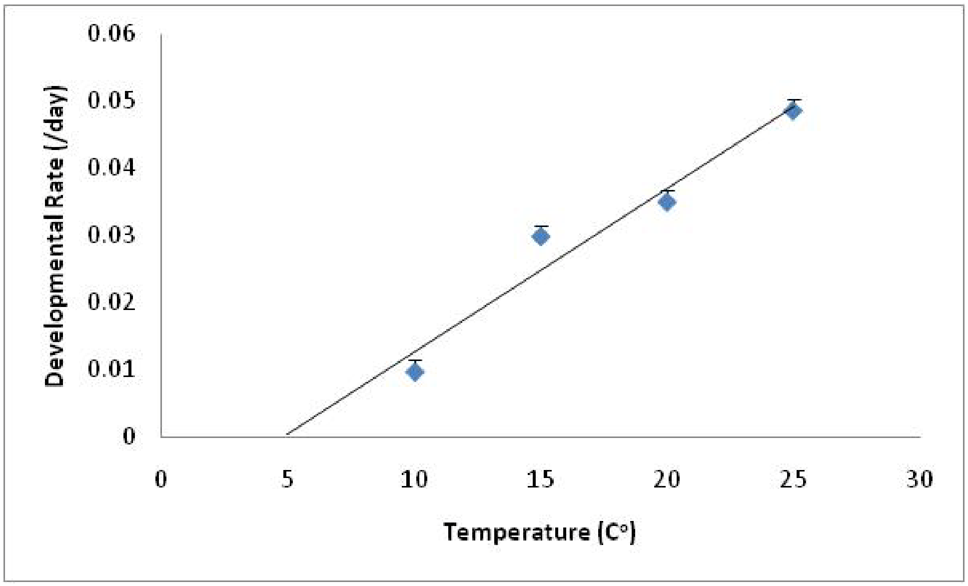
Lower threshold (° C)	DD (C°) Accumulation (1/1-5/1/07)	DD (F°) Accumulation (1/1-5/1/07)	DD (C°) Accumulation (1/1-5/1/08)	DD (F°) Accumulation (1/1-5/1/08)
3.46	400.2	720.4	281.8	507.2
3.70	385.1	693.2	266.3	479.3
4.81	322.3	580.1	211.4	380.5

Pear psylla nymph developmental rate also demonstrated a linear relationship among the four constant temperatures examined (Table 3, Figure 2). Pear psylla development from eclosion through adult emergence was markedly slower than egg development (5 developmental stages v 1 stage). There was little variation in mortality among the four temperature treatments (survivorship at 10, 15, 20, and 25°C: 85%, 78%, 85%, and 90%, respectively). The linear model was again a good fit for the data ($p < 0.0001$), and regression coefficient was again significant ($r^2 = 0.95$).

Table 3. Mean developmental rates of pear psylla nymphs (eclosion to emergence) maintained at constant temperature.

Temperature (°C)	Developmental Rate / Day	Standard Deviation
10	0.00979	0.00168
15	0.029979	0.007902
20	0.035112	0.008753
25	0.0487	0.006799

Figure 2. Mean developmental rate of pear psylla nymphs (±SD) and the linear regression of rate on temperature treatment. $y=0.0024 \cdot T - 0.0118$, where y is developmental rate and T is temperature.



Using the regression model, the temperature threshold for egg development of *Cacopsylla pyricola* was estimated to be 4.92°C (40.85°F). This is again higher than the estimates for *Cacopsylla pyri* from Schaub et al. (2005) of 3.43 °C and 3.38 ° C from Sonnemaison and Missionier (1956; calculated in Schaub et al. 2005).

Data from the field observations have not been tested against the preliminary model as there are some issues that require further examination. Preliminary model estimates of degree-day accumulations for the 2007 and 2008 growing seasons result in accumulations of 2425 and 2110 degree-days (C°-based; 4047 and 3803 F°-based) for the period from Jan 1 to Sept 1. Using preliminary data, this gives an estimate of 3 to 3.5 generations per year of pear psylla. Observations in the field indicate that there are at least 5 generations of pear psylla in experimental orchards, where no control tactics were used. However, in commercial orchards where relatively low densities of pear psylla were present, there may be fewer generations present; the low densities, in combination with the sampling methods and patchy distribution of the insects, prevent generations from being easily distinguished. Alternatively, high density populations of pear psylla may rapidly begin to overlap; the time-lag associated with this overlap needs to be examined. While the model predictions do not correspond to the field observations in the experimental orchards, where populations of pear psylla populations were very high, predictions may correspond to the sites with relatively low densities.

An additional factor that may make this discrepancy between predicted and observed development in high and low density populations important could be the use of kaolin clay in the prebloom period, and other insecticides throughout the season. The orchards in which the populations were low were treated with kaolin, and other insecticides were also used through the season. However, the orchards that harbored high populations of pear psylla were untreated throughout the season (hence the very high densities). Thus, in very high densities the observed 5-6 generations may be possible, and the model may still be correctly predicting 3 generations in low populations. Nevertheless, further development of the model is necessary, as is continued data collection for field validation.

Further development of the pear psylla phenology model will continue through the winter and into the 2009 growing season, without any further request for funding.

Literature Cited:

Bonnemaison, L. and J. Missonnier. 1956. Le psylle du poirier (*Psylla pyri* L.): morphologie et biologie. Méthode de Lutte. Annales Epiphyties 7: 263–231.

Schaub, L., B. Graf, and A. Butturini. 2005. Phenological model of *Cacopsylla pyri*. Entomol. Experiment. et Applic. 117: 105-111.

EXECUTIVE SUMMARY

The objective of this project is to develop a degree-day model for better predicting the development of pear psylla, *Cacopsylla pyricola*. Degree-day models have become very useful in pest management for predicting development of several insect pests, particularly codling moth and leafrollers. Using temperature-based insect development models allows fruit growers to improve the timing of monitoring efforts, better estimate population densities and thresholds, and better time insecticide sprays for maximum efficacy.

Pear psylla has not been a focus of developing phenology models in the past because the generations can become overlapping early in the season, reducing the ability to time efforts at particular life stages. However, with the development of new insect control tactics using kaolin clay and insect growth regulators, the oviposition of the overwintering adults and emergence of the first generation become truncated. This allows for the potential prediction of discrete generations through subsequent season.

Laboratory studies were conducted in 2007 and 2008 to determine the temperature requirements at the threshold where development begins for pear psylla eggs and nymphs, and the rates at which development occurs at higher temperatures. The temperature threshold for egg development was determined to be 4.81^{o}C (40.65^{o}F), which is higher than those reported for *Cacopsylla pyri*. The lower threshold for pear psylla nymph development was determined to be 4.92^{o}C (40.85^{o}F), also higher than for *C. pyri*. Developmental rates for both life stages were linear with increasing temperatures, and the regression lines were statistically significant for both eggs and nymphs ($p<0.0001$ for both eggs and nymphs, $r^2=0.72$ and 0.95, respectively).

During the growing seasons of 2007 and 2008, field observations in experimental (controlled) and commercial (uncontrolled) pear orchards were made of pear psylla developmental times, along with temperature measurements. These data are still being evaluated with respect to the developmental times predicted from the model. Field observations from Jan 1 through Sept 1 in experimental orchards indicate the occurrence of at least 5 generations of pear psylla each year. However, the developmental model predicts that the degree-day accumulations for each year would allow only 3 to 3.5 generations per year. This discrepancy is being investigated, and further field studies are necessary.

There are two major factors which may cause the discrepancy between model prediction and field observation. First, the density of pear psylla may interfere with the ability to estimate the generations. In untreated, high pear psylla population orchards there may be overlap in life stages occurring early in the season, which may increase the estimate generations. Alternatively, in orchards with low pear psylla densities where kaolin and other insecticides were used during the season, there may be fewer generations, but it is difficult to determine because of the relatively low numbers of eggs and nymphs observed, and the variation associated with them. Further examination is necessary.

Development of the pear psylla phenology model will continue through the winter and into the 2009 growing season, without any further request for funding.