Predicting Pest Activity with Degree-Day Models
Outline

- Temperature effects on insect and plant biology
- Degree-days Models
- How forecasting helps crop management
- Where to find resources
Insect Biology

- Insects are cold-blooded
- Growth is controlled by temperature
- Minimum temperature for development
- Maximum temperature
Development rate of plants is also temperature dependent.
Temperature & Onion Thrips

- Survivorship
- Reproduction
- Generation Time
- Population Dynamics
## Onion Thrips Survival, Fecundity and Generation Times (Days) at Various Temperatures

<table>
<thead>
<tr>
<th></th>
<th>68°F</th>
<th>77°F</th>
<th>86°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adulthood</td>
<td>47</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Eggs / Female</td>
<td>210</td>
<td>165</td>
<td>63</td>
</tr>
<tr>
<td>Generation Time</td>
<td>48</td>
<td>30</td>
<td>17</td>
</tr>
</tbody>
</table>

Murai (2000)
# Onion Thrips Population Growth

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1</td>
<td>1</td>
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<tr>
<td>June 8</td>
<td></td>
</tr>
<tr>
<td>June 15</td>
<td></td>
</tr>
<tr>
<td>June 22</td>
<td></td>
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<tr>
<td>June 29</td>
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<tr>
<td>July 6</td>
<td></td>
</tr>
<tr>
<td>July 13</td>
<td></td>
</tr>
<tr>
<td>July 20</td>
<td>210</td>
</tr>
<tr>
<td>July 27</td>
<td></td>
</tr>
<tr>
<td>August 3</td>
<td></td>
</tr>
<tr>
<td>Number generations</td>
<td>1</td>
</tr>
</tbody>
</table>
## Onion Thrips Population Growth

<table>
<thead>
<tr>
<th>Date</th>
<th>68°F</th>
<th>77°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>June 8</td>
<td></td>
<td></td>
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<tr>
<td>June 15</td>
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<td></td>
</tr>
<tr>
<td>June 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 29</td>
<td></td>
<td>165</td>
</tr>
<tr>
<td>July 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 20</td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>July 27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August 3</td>
<td></td>
<td>27,225</td>
</tr>
<tr>
<td>Number generations</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
# Onion Thrips Population Growth

<table>
<thead>
<tr>
<th>Date</th>
<th>68°F</th>
<th>77°F</th>
<th>86°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>June 8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 15</td>
<td></td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>June 22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 29</td>
<td>165</td>
<td></td>
<td>3,969</td>
</tr>
<tr>
<td>July 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 13</td>
<td></td>
<td></td>
<td>250,047</td>
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<tr>
<td>July 20</td>
<td>210</td>
<td></td>
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</tr>
<tr>
<td>July 27</td>
<td></td>
<td></td>
<td>15,752,961</td>
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<tr>
<td>August 3</td>
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<td></td>
</tr>
<tr>
<td>Number generations</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
How to Use Development Rates in Crop Management?

• Predict timing of pest populations

• Improve scouting

• Improve timing of pesticide applications
Quiz

• How long does it take a codling moth eggs to hatch?

a) 8 days
b) 11 days
c) 14 days
d) All of the above
Degree-Day Models as a Tool

Use to predict when susceptible pest stages are present to maximize control
• Degree-days (DD) are used in models because they allow a simple way of predicting development of cold-blooded organisms (insects, mites, bacteria, fungi, plants).
Degree - Day

• Degree-day: used to measure insect development
• Amount of heat accumulated over a specified base temperature during a 24 hour day.
• 1 degree-day (DD) – single degree of temperature above an insect’s lower threshold maintained for 24 hours
Daily temperature readings can be used to calculate growing degree-days, which is a measure of accumulated heat.
Base Temperature

- Temperature above which degree-day accumulation is calculated
- Ideally, the base temperature is the lower temperature threshold for development or activity
Lower Temperature Threshold

Temperature below which no growth or development occurs in the species of interest.
Cumulative Degree - Days

• Number of degree-days accumulated during a specified time interval (e.g. since the beginning of the year).

• Calculated in reference to the starting date
Key Point

- Degree-days only have meaning if base temperature and starting date are specified.
Calculating Degree-Days

• Average method

• Modified average method

• Modified sine wave
Average Method

DD = Average Temp – Base Temp

Max = 70, Min = 40

Base = 50

\[
\frac{70 + 40}{2} - 50 = 5 \text{ DD}
\]
Average Method

DD = Average Temp – Base Temp

Max = 80, Min = 50

Base = 50

\[
\frac{80 + 50}{2} - 50 = 15\text{ DD}
\]
Modified Sine Wave Method

Temperature

24 Hour Day
Upper Temperature Threshold

Temperature above which no growth or development occurs.
Upper Temperature Threshold
Limitations of Degree-Day Models

- Insect response to temperature is not linear.
- Thresholds known for very few species.
- Measured temperatures not the same as those experienced by the pest.
Degree-Day Models

- Predict timing of events
- Guidelines to help time scouting efforts
- Improve crop management
Codling Moth Development
Predicting Codling Moth

• Overwinter as mature larvae

• Adult flight begins around full bloom

• Larvae bore into fruit

Codling moth usually develops through two generations a year in the Northwest. In warm years, a partial third generation may be produced. Timings are based on observations on Red Delicious apples in Washington.
Two Methods to Manage Larvae

Calendar Approach
• Treat 3 weeks after full bloom

Degree Day Model
• Monitor adult flight with pheromone traps
• Biofix = 1^{st} consistent catch of moths in traps
• Treat at 250 DD after Biofix
## Comparison of Spray Timing Methods for Codling Moth

<table>
<thead>
<tr>
<th>Year</th>
<th>Full bloom</th>
<th>Biofix (1st moth)</th>
<th>Calendar method</th>
<th>Model method</th>
<th>Observed 1st entry</th>
<th>Model accuracy</th>
<th>Calendar accuracy</th>
<th>Days between biofix and 1st entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>Apr 28</td>
<td>Apr 29</td>
<td>May 19</td>
<td>May 22</td>
<td>May 22</td>
<td>0</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>80</td>
<td>Apr 26</td>
<td>Apr 27</td>
<td>May 17</td>
<td>May 21</td>
<td>May 21</td>
<td>0</td>
<td>4</td>
<td>24</td>
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<tr>
<td>81</td>
<td>Apr 23</td>
<td>Apr 22</td>
<td>May 14</td>
<td>May 29</td>
<td>May 27</td>
<td>-2</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td>82</td>
<td>May 5</td>
<td>May 3</td>
<td>May 26</td>
<td>May 28</td>
<td>May 28</td>
<td>0</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>83</td>
<td>Apr 24</td>
<td>Apr 28</td>
<td>May 15</td>
<td>May 24</td>
<td>May 23</td>
<td>-1</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>84</td>
<td>Apr 30</td>
<td>May 6</td>
<td>May 27</td>
<td>June 8</td>
<td>June 8</td>
<td>0</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>85</td>
<td>Apr 30</td>
<td>Apr 29</td>
<td>May 21</td>
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<td>1</td>
<td>23</td>
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<tr>
<td>86</td>
<td>Apr 25</td>
<td>May 1</td>
<td>May 16</td>
<td>May 29</td>
<td>May 29</td>
<td>0</td>
<td>13</td>
<td>28</td>
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<tr>
<td>87</td>
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<td>Apr 20</td>
<td>May 14</td>
<td>May 10</td>
<td>May 12</td>
<td>2</td>
<td>-2</td>
<td>22</td>
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<tr>
<td>93</td>
<td>May 6</td>
<td>May 5</td>
<td>May 26</td>
<td>May 20</td>
<td>May 20</td>
<td>0</td>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>

**Biofix:** The first capture of male moths in pheromone traps.

**Calendar method:** Spray 21 days after full bloom.

**Model method:** Spray 250 degree days after biofix.

**Accuracy:** Difference, in days, between observed first larval entry in the field and predicted timing. Negative numbers indicate predicted timing was too late; positive numbers indicate predicted timing was too early.
Alfalfa Weevil
Alfalfa Weevil

• Short time between when the insect emerges from its overwintering site in leaf litter to depositing eggs into the terminal leaders and egg hatch.

• If treatments are timed on a calendar date alone, it may not be effective since insect development is related to temperature.
Alfalfa Weevil

• Sampling fields can save money by avoiding unnecessary pesticide application.

• Crop damage can be reduced by using an insecticide at the time of greatest effectiveness.
## Alfalfa Weevil Development

<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Degree Days to Complete Life Stage</th>
<th>Accumulated Degree Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>egg</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>1st instar</td>
<td>71</td>
<td>371</td>
</tr>
<tr>
<td>2nd instar</td>
<td>67</td>
<td>438</td>
</tr>
<tr>
<td>3rd instar</td>
<td>66</td>
<td>504</td>
</tr>
<tr>
<td>4th instar</td>
<td>91</td>
<td>595</td>
</tr>
<tr>
<td>Pupa</td>
<td>219</td>
<td>814</td>
</tr>
</tbody>
</table>

Base = 48°F Start = January 1
## Degree Days - Alfalfa Weevil Eggs

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Degree Days as of April 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>304</td>
</tr>
<tr>
<td>2009</td>
<td>203</td>
</tr>
<tr>
<td>2010</td>
<td>353</td>
</tr>
<tr>
<td>2011</td>
<td>143</td>
</tr>
<tr>
<td>2012</td>
<td>460</td>
</tr>
<tr>
<td>Average of 5 years</td>
<td>292.5</td>
</tr>
</tbody>
</table>

(Central Michigan)
Lygus 2011 vs. 2012

Peak 1st & 2nd instars

Cumulative sine DDs (52°F base)

Peak 1st & 2nd instars nymphs
Other Uses for Degree-Day Models

- Crop Maturity
- Disease Forecasting
Corn Maturity Relative to Degree-Days

Figure 1. Relationship between hybrid comparative relative maturity (CRM) and hybrid growing degree units (GDU) from planting to kernel black layer for a group of Pioneer® brand corn hybrids(1). (Source of data: Pioneer Hi-Bred International sales literature, 2001.)

The graph shows a linear relationship with the equation:

\[ y = 24.908x - 82.821 \]

and an R² value of 0.9273.
Figure 3. Accumulated corn GDUs during May 1 to August 31st in Parkston, SD for 2008, 2009 & 2010.
Disease Forecasting

• Temperature
• Leaf Wetness
• Calculate DSV – Disease Severity Values
• Requires monitors for temperature & moisture
## Tom-Cast Model

<table>
<thead>
<tr>
<th>Mean Daily Temp</th>
<th>Hours of Leaf Wetness to Produce</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 – 6</td>
</tr>
<tr>
<td>55 – 63</td>
<td></td>
</tr>
<tr>
<td>64 – 68</td>
<td>0 – 3</td>
</tr>
<tr>
<td>70 – 77</td>
<td>0 – 2</td>
</tr>
<tr>
<td>79 – 84</td>
<td>0 – 3</td>
</tr>
<tr>
<td><strong>DSV</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>
Where to find resources?

Welcome to the USPEST.ORG/PNWPEST.ORG/IPPC2.ORST.EDU web server at the Integrated Plant Protection Center of Oregon State University

The following web sites/resources are hosted here:

1. http://uspest.org/wea - Online IPM Pest and Plant Disease Models and Forecasting - for agricultural, pest management, and plant biosecurity decision support in the US; including:
   ○ http://uspest.org/cgi-bin/ddmodel.pl Pacific NW interface to degree-day models and calculations.
   ○ Online daily degree-day maps / tables. GIS mapping, degree-day and plant disease risk modeling system for:
     Main index to online tutorials, daily DD maps, models linked from weather stations (tables)
   ○ http://uspest.org/risk/models Online plant disease risk and phenology models and degree-day calculations.
   ○ http://uspest.org/cgi-bin/usmapmaker.pl Custom degree-day mapping calculator for 48 US states

2. Online publishing engine and decision support system for Pacific Northwest Pest Management Handbooks:
   ○ http://uspest.org/pnw/weeds PNW Weed Management Handbook - from 2001 - 2010, now this link forwards to a new site hosted by OSU EESC


USPEST.ORG
Online Phenology and Degree-day Models
for agricultural and pest management decision making in the US

Degree-day Calculator

Select degree-day model list or calculator mode instructions:
Degree-Day Calculator calculator general introduction
(hint: select all form options, click here: and make a bookmark for later use)

For calculator mode, enter thresholds in °F (or celsius °C: ) and calculation method:
lower: upper: ° single sine

Select starting Jan 1 2013 and ending Dec 31 2013 dates
Starting date/BIOFIX instructions:

Select location: Only one column should display a location, otherwise "None"

Oregon, California, Alaska

Washington, Idaho

Montana, Wyoming

Or upload your own weather data file to calculate: (see format description or example file)
Choose File No file chosen

Forecasts: NWS zipcode/city, state: or weather.com site: None

Select historical average forecast location: Should line up with selected location above

None

None

None

Output: Simple header Table Graph Include precipitation in graph

Click here to run the model: Calc Reset: Clear all values
Degree-day Calculator

Select degree-day model list or calculator mode instructions:

Degree-Day Calculator calculator general introduction
apple maggot 1st emerge [cherry & apple] Jones et al. 1989 JEE 82:788
apple maggot percent emergence [cherry & apple] Jones et al. 1989
apple scab infection season [apple] Gadoury et al. (1995)
pear scab infection season [pear] Hood River Exp. Sta./Bob Spotts
bertha armyworm [vegetables] Bailey 1976
black cutworm [vegetables] Luckmann et al. 1976
brown marmorated stink bug [multiple hosts] Nielsen et al 2008
Barley Miller MSU
cabbage looper [vegetables] Toba et al. 1973
corn earworm [sweet corn] Hartstack et al. 1976
chick Pea (Desi) int. grwth, req. stress to hasten matur. Miller MSU

codling moth revised 06 [apple & pear] 2006 revision by A. L. Knight
codling moth WSU model [apple & pear] Jones, Doerr & Brunner 2008
cereal leaf beetle [grasses and grains] Fulton et al 1975 EE 4:357 OSU
codling moth [apple & pear] Brunner and Hoyt (1987)
cabbage maggot - Dreves 2005 newsletter (pdf)
canola (Arg) ind. grwth-cont. to flwr until stressed Miller MSU

Output: Simple header Table Graph Include precipitation in graph

Click here to run the model: Calc Reset: Clear all values
IPM Resources

Disease Forecast Systems

Pesticide Information Centers/Services

Pest Identification and Management

General pest, disease, and other problems of vegetables; identification and management resources

Cucurbit resources
Onion resources
Tomato resources
Legume resources
Potato resources

The resources listed below are for informational purposes only, and do not imply recommendation or endorsement by the PNW VEG.

Disease Forecast Systems

2010 Potato Insect Pest Survey for the Columbia Basin of Washington, Washington State University

Onion Disease Forecast Models for the northeastern U.S., New York State Integrated IPM Program, and Network for Environment and Weather Applications (NEWA)

Potato Disease Forecast Models for the the northeastern U.S., New York State Integrated IPM Program, and Network for Environment and Weather Applications (NEWA)
How to Manage Pests

Degree-days: Codling Moth in Apples

Use this program to run a model of codling moth in apples, recommended by UC Cooperative Extension. In calculating degree-days, the program uses temperatures from the UC IPM weather database, a file you supply, or data you enter online.

How to use this model in: apples, pears, plums, prunes, walnuts, or landscape
| Sunset temperatures | Calculate any degree-days | Using this calculator | Reference degree-day tables | About degree-days |

Codling Moth in Apples

- Lower/upper threshold: 50/88°F
- Calculation/upper cutoff method: single sine/horizontal
- Biofix: The first biofix is the first date that moths are consistently found in traps and sunset temperatures have reached 62°F.
- Additional information on using this model: Pest Management Guideline

Specify source of temperature data

Select the source of temperatures to be used to calculate degree-days. You may also use your own maximum and minimum temperatures and look up approximate daily degree-day values in a reference degree-day table for codling moth, then total them yourself.

Select from stations in which California county?

- Modoc
- Mono
- Monterey
- Napa
- "Nevada" checkbox selected

Include active stations only

Set time period for running model

- Biofix (start date): March 15, 2013
- End date: February 16, 2013

Biofix (start date): The first biofix is the first date that moths are consistently found in traps and sunset temperatures have reached 62°F.

Submit button with options: [Choose File] No file chosen [Text file (comma or tab delimited) format]
Questions?

"Harris, when I said 'any questions' I was using only a figure of speech."