Generic models for pests and diseases

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A Simple Generic Infection Model for Foliar Fungal Plant Pathogens

AIM:

The model predicts infection period by fungal plant pathogen.
It estimates W(T) the wetness duration (in hours) required to critical disease threshold: 20% disease incidence or 5% disease severity

$$f(T) = \left[\frac{T_{max} - T}{T_{max} - T_{opt}}\right] \left[\frac{T - T_{min}}{T_{opt} - T_{min}}\right]^{(T_{opt} - T_{min})/(T_{max} - T_{opt})}$$

f(T)= temperature function
T= mean temperature (°C) during wetness period
Tmin= minimun temperature for infection (°C)
Tmax= maximum temperature for infection (°C)
Topt= optimum temperature for infection (°C)

W(T) = Wmin/f(T) ≤ Wmax

W(T)=leaf wetness duration for infection (h)

Wmin= minimum value of the wetness duration requirement for infection (h)

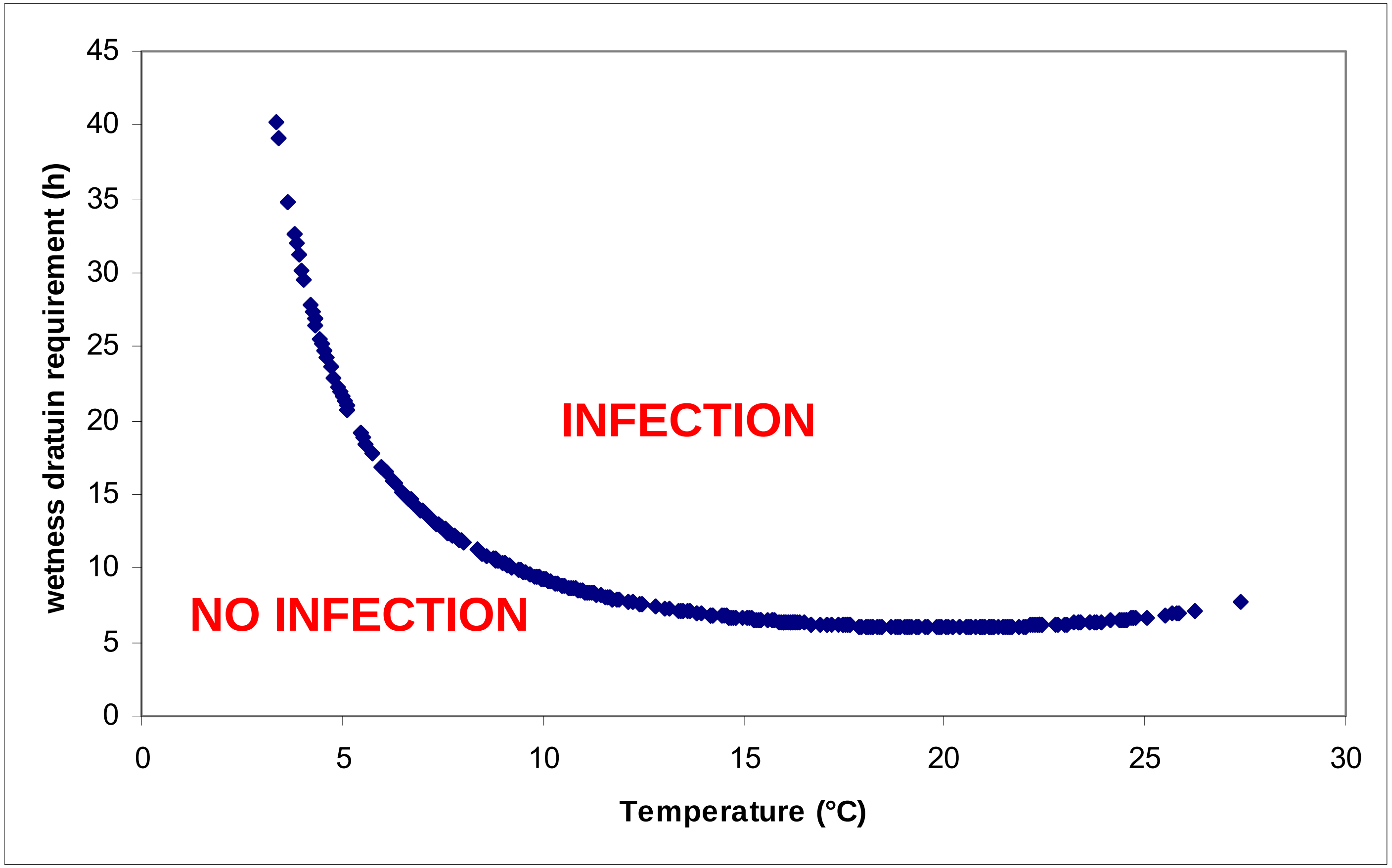
Wmax= optimum value of the wetness duration requirement for infection (h)

TABLE 2. Infection model parameters and statistical comparison between model predictions and observations based on published studies relating fungal infection to temperature and wetness duration

Pathogen	Host[a]	Ref.[b]	Ref. T_{min}[c]	T_{min}[d]	T_{max}[e]	T_{opt}[f]	W_{min}[g]	W_{max}[h]	Obs[i]	r[j]	RMS[k]	SRMS[l]
Albugo occidentalis	Spinach	81	...	6	28	16	3	12	12	0.87	2.8	0.9
Alternaria brassicae	Oilseed rape	38	6	2.6	35	18	6	22	9	0.96	4.0	0.7
Alternaria cucumerina	Muskmelon	31	...	12	25	19	8	24	6	0.98	1.6	0.2
Alternaria mali	Apple	32	...	1	35	23	5	40	16	0.88	5.2	1.0
Alternaria porri	Onion	80	...	1	35	23	8	24	5	1.00	0.7	0.1
Alternaria sp.	Mineola tangelo	18	...	9.4	35	25	8	16	5	0.90	1.3	0.2
Ascochyta rabiei	Chick pea	84	...	1	35	25	12	48	6	0.10	19.2	1.6
Bipolaris oryzae	Rice	59	25	8	35	27.5	10	24	6	0.78	5.0	0.5
Botryosphaeria dothidea	Apple fruit	58	...	8	35	28	8	19	6	0.95	1.6	0.2
Botryosphaeria obtuse	Apple fruit	7	...	1	35	26	5	40	7	0.97	3.2	0.6
Botrytis cinerea	Grape	56	57	10	35	20	4	10	11	0.94	0.8	0.2
Botrytis cinerea	Strawberry flower	15	...	5	35	25	8	18	7	0.13	5.0	0.6
Botrytis cinerea	Grape flower	56	57	1	34	25	1	12	6	0.99	0.6	0.6
Botrytis squamosa	Onion	82	...	1	28	18	15	24	8	0.50	4.7	0.3
Bremia lactucae	Lettuce	67	...	1	25	15	4	10	6	0.98	0.8	0.2
Cercospora arachidicola	Peanut	93	6	13.3	35	24	24	48	5	0.72	8.9	0.4
Cercospora carotae	Carrot	20	...	11	32	24	28	96	5	0.98	16.5	0.6
Cercosporidium personatum	Peanut	17	6	8	35	20	16	33	6	0.33	6.0	0.4
Coccomyces hiemalis	*Prunus* sp.	28	29	4	30	18	5	30	11	0.96	7.8	1.6
Colletotrichum acutatum	Strawberry fruit	92	...	7	35	27.5	6	36	6	0.93	4.4	0.7
Colletotrichum orbiculare	Watermelon	53	...	7	30	24	2	16	7	0.69	5.6	2.8
Didymella arachidicola	Peanut	79	6	13.3	35	18.5	24	210	5	–0.10	55.5	2.3
Diplocarpon earlianum	Strawberry	98	51	2.9	35	22.5	12	18	5	0.53	3.2	0.3
Guignardia bidwellii	Grape	76	...	7	35	27	6	24	10	0.74	5.1	0.9
Gymnosporangium juniperi-virginianae	Apple	4	...	1	35	21	2	24	12	0.99	1.1	0.5
Leptosphaeria maculans	Oilseed rape	12	6	2.6	35	18.5	7	18	5	0.81	4.8	0.7
Melampsora medusae	Poplar	50	...	12	28	20.5	5	12	10	0.96	0.7	0.1
Monilinia fructicola	Prunus fruit	13	44	10	35	20	10	16	5	0.96	0.9	0.1
Mycosphaerella pinodes	Pea	61	6	1.4	35	20	6	72	6	1.00	21.9	3.7
Phakopsora pachyrhizi	Soybean	48	6	10	28	23	8	12	6	0.86	1.3	0.2
Phytophthora cactorum	Apple fruit	36	...	1	35	25	2	5	6	0.97	0.4	0.2
Phytophthora cactorum	Strawberry fruit	37	...	6	35	20.5	1	3	8	0.85	0.6	0.6
Phytophthora infestans	Potato	62	19	1	28	15	6	12	6	0.53	3.2	0.5
Plasmopara viticola	Grape	43	...	1	30	20	2	14	6	0.99	0.6	0.3
Pseudoperonospora cubensis	Cucumber	23	1	1	28	20	2	12	6	0.98	0.7	0.4
Puccinia arachidis	Peanut	16	6	5	35	25	5	25	5	0.82	5.2	1.0
Puccinia menthae	Peppermint	27	...	5	35	15	6	12	5	0.87	1.6	0.3
Puccinia psidii	Eucalyptus	63	52	1	30	21.5	6	24	5	0.98	3.9	0.6
Puccinia recondita	Wheat	85	6	2.6	30	25	5	16	6	0.61	5.4	1.1
Puccinia striiformis	Wheat	24	6	2.6	18	8.5	5	8	6	0.99	0.2	0.0
Pyrenopeziza brassicae	Oilseed rape	34	6	2.6	24	16	6	24	7	0.90	3.6	0.6
Pyrenophora teres	Barley	11	6	2.6	35	23	3	6	4	0.95	0.4	0.1
Pyrenophora teres	Barley	72	6	2.6	35	18	5	48	4	1.00	11.9	2.4
Rhynchosporium secalis	Barley	94	6	2.6	30	22.5	12	48	4	0.98	4.2	0.4
Rhynchosporium secalis	Barley	65	6	2.6	30	22.5	6	19	6	0.94	2.3	0.4
Sclerotinia sclerotiorum	Bean	91	...	1	30	25	48	144	5	0.88	24.0	0.5
Septoria glycines	Soybean	70	6	10	35	25	6	18	4	0.83	4.2	0.7
Venturia inaequalis	Apple	78	...	1	35	20	6	40.5	26	0.65	2.7	0.5
Venturia pirina	Pear	77	...	1	35	22	10	25	7	0.98	1.3	0.1
Venturia pirina	Pear	87	...	1	35	20	10	30	7	0.99	1.5	0.1
Wilsonomyces carpophilus	Almond	71	...	5	35	25	12	48	9	0.92	6.6	0.6

[a] Foliage unless otherwise noted.
[b] Reference to temperature-wetness combination study.
[c] Reference for estimation of T_{min} from crop development.
[d] T_{min} = minimum temperature for infection (°C).
[e] T_{max} = maximum temperature for infection (°C).
[f] T_{opt} = optimum temperature for infection (°C).
[g] W_{min} = minimum value of the wetness duration requirement for infection (h).
[h] W_{max} = optimum value of the wetness duration requirement (h).
[i] Number of temperature/wetness combinations included as observations.
[j] r = Pearson's correlation coefficient (54).
[k] RMS = root mean square error (75).
[l] SRMS = standardized root mean square/W_{max}.

EXAMPLE: VENTURIA INAEQUALIS



SENSITIVITY TO DRY INTERRUPTIONS OF FUNGAL FOLIAR PATHOGEN

Classification of fungal foliar pathogens based on their ability to withstand interruptions to wetting during infection based on published studies relating infection to temperature and wetness duration

Sensitivity to dry interruption	D_{50}[a]	Species	Reference
Sensitive	1–2 h	*Puccinia recondita*	85
		Puccinia striiformis	85
		Pyrenophora tritici-repentis	66
Moderate	4–20 h	*Alternaria brassicae*	55
		Alternaria linicola	88
		Alternaria porri	80
		Ascochyta rabiei	84
		Bipolaris oryzae	59
		Botryosphaeria obtusa	8
		Botrytis squamosa	3
		Cercospora kikuchii	68
		Coccomyces hiemalis	28
		Stagonospora nodorum	41
		Uromyces phaseoli	9
		Venturia pirina	86
Insensitive	≥24 h	*Cercospora carotae*	21
		Mycosphaerella graminicola	73
		Stemphylium botryosum	9
		Venturia inaequalis	10,86

[a] D_{50} is defined as the duration of a dry period at relative humidities of <95% that will result in a 50% reduction in infection compared with a continuous wetness period.

Generic Infection Model

By Roger Magarey

The Generic infection model calculates predicted infection severity values for a given wetness duration and

$$I = W f_{(T)} / W_{min} \geq W / W_{max}$$

where, W = wetness duration h, $f_{(T)}$ = temperature response function, and $W_{min,\ max}$ = the minimum and maximum value of the wetness duration requirement.

The temperature moisture response function is based on Wang and Engel 1998. This was shown to be very close to the temperature function of Yin, used in the

$$[f_T(T, T_{min}, T_{opt}, T_{max})] = \begin{cases} \frac{2(T-T_{min})^{\alpha}(T_{opt}-T_{min})^{\alpha}-(T-T_{min})^{2\alpha}}{(T_{opt}-T_{min})^{2\alpha}}; & \text{if } T_{min} \leq T \leq T_{max} \\ 0 ; & \text{if } T < T_{min} \text{ or } T > T_{max} \end{cases} \quad [-] \qquad (6)$$

In worksheet daily

F1	= (a b- c)/d	Wang and Engel 1998 Eqn 6
F2	= Wmin/F1	Magarey et al 2005 Eqn 1

Model Outputs	**Comments**
1. Infection model output	This variable calculates infection from Wmin and Wmax and F2
2. Accumulated infection output	Accumulation of above
3. Infection output (Precip days only)	This infection variable incorporates the splash requirement
4. Accumulated infection oputput (precip days only)	Accumulation of above
5. Infection events	Major infection events, initated by rain and continue from previous day or with additional rain.

Inputs

Input weather data must be pasted into daily

Average temperature

Leaf wetness h/day

Precipitation

Parameters

Parameter values must be entered into Parameters worksheet

Tmin	Mininimum temperature for infection
Tmax	Maximum temperature for infection
Topt	Optimum temperature for infection
Wmin	Minimum wetness duration requirement
Wmax	Maximum wetness duration requirment
Precipitation	Precipitation threshold for infection
Continuation	Interruption value

Using Growing Degree Days For Pest Management

The effect of temperature on insect developing rate is often described by using a thermal time concept.
The growing degree-days (GDD) is a commonly used thermal time method.

It relates development rate linearly to temperatures above the lower threshold (often referred to as the base temperature below which the development stops).

In some applications of the GDD procedure, the upper temperature threshold is introduced, above which the development rate stops.

Calculation of Growing Degree Days

The traditional method is based on accumulation of daily mean temperature between lower and upper thresholds.

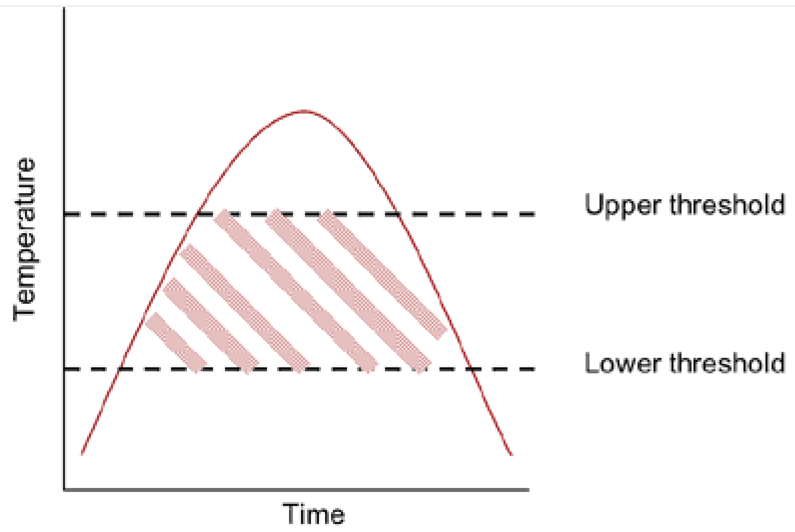
$$GDD_{TOT} = \Sigma (GDD_{Daily})$$

if Tmed < Tinf $\quad$ **$GDD_{daily} = 0$**

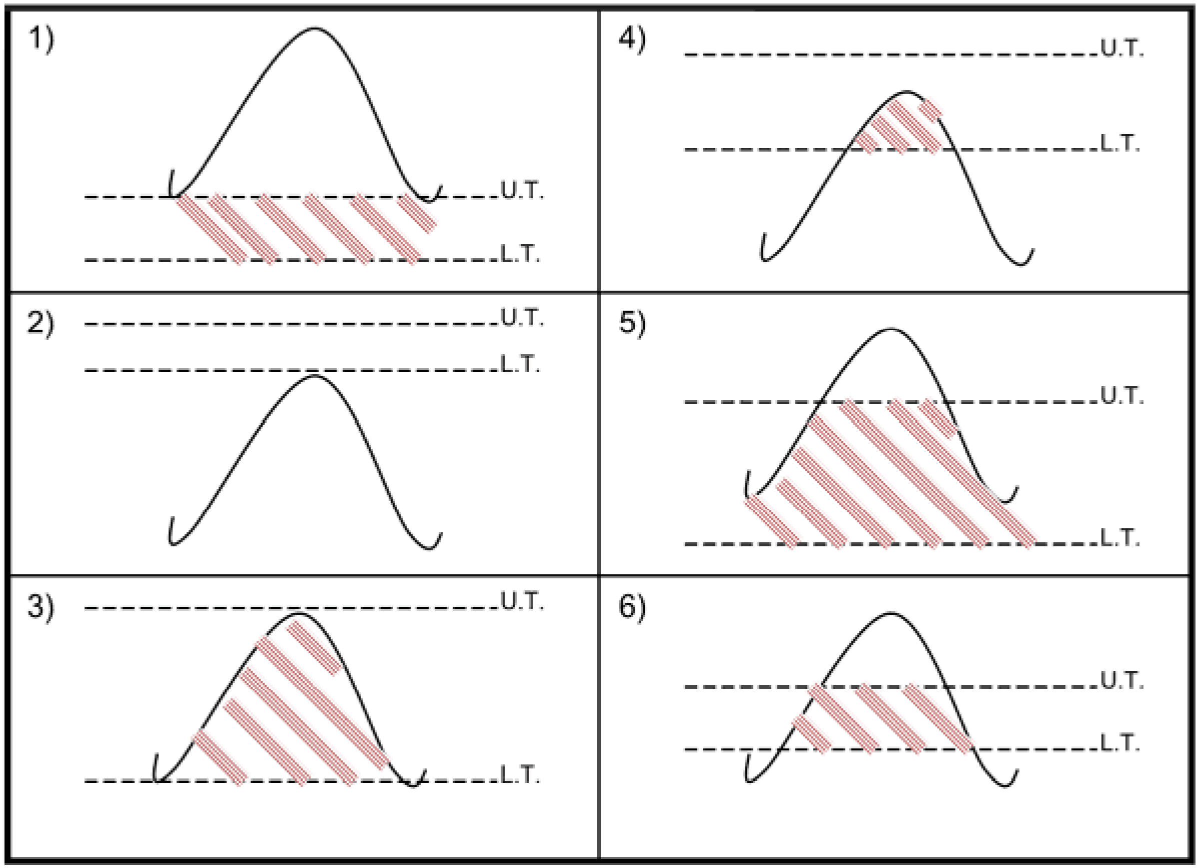
if Tmed > Tsup $\quad$ **$GDD_{daily} = Tsup - Tinf$**

if Tinf < Tmed < Tsup $\quad$ **$GDD_{daily} = Tmed - Tinf$**

where
Tmed is daily mean temperature;
Tinf lower threshold;
Tsup upper threshold.



Temperature
Upper threshold
Lower threshold
Time



1)
U.T.
L.T.
2)
U.T.
L.T.
3)
U.T.
L.T.
4)
U.T.
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5)
U.T.
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6)
U.T.
L.T.

AVERAGE METHOD

Degree days can be calculated using a simple formula for the average daily temperature, calculated from the daily maximum and minimum temperatures,
minus the baseline (lower developmental threshold):

[(daily maximum temperature + daily minimum temperature)/2] – baseline temperature.

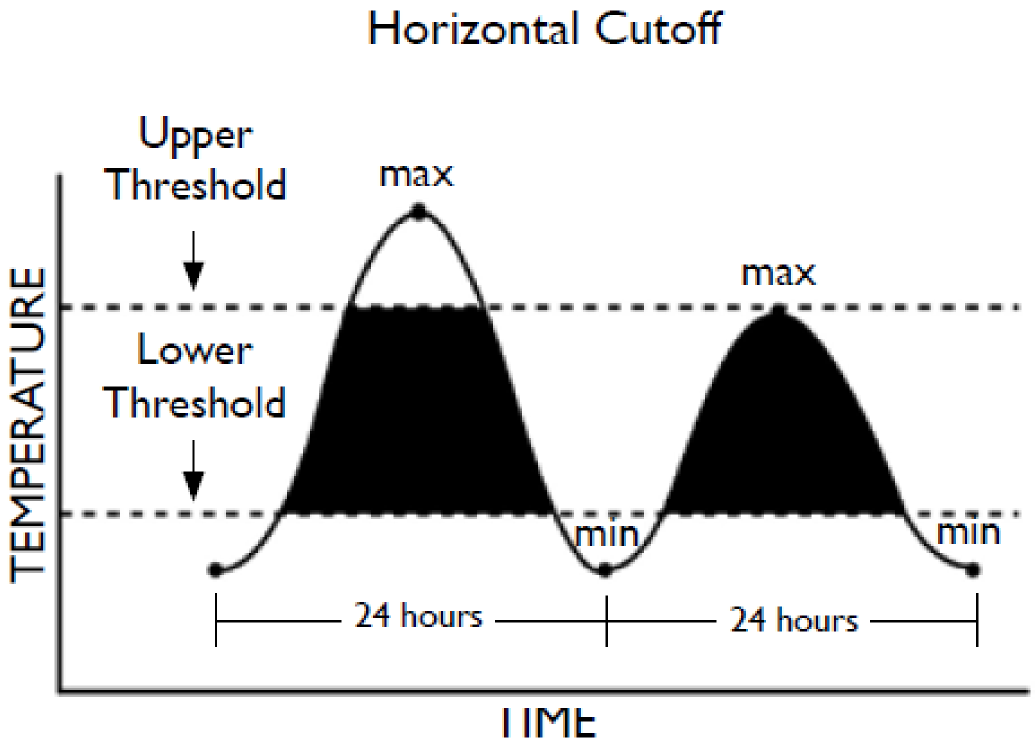
This calculation method is the simplest and least precise.

SINE WAVE METHOD

It is based on the assumption that temperatures of a 24-hour day follow a sine wave curve. The number of degree days is then calculated as the area under this curve within the lower and upper temperature thresholds

SINE WAVE METHOD

The area in black under the curve represents the number of degree days that fall between a lower and upper threshold, for each 24-hour period



partial list of insect pests that occur in Utah for which we have temperature thresholds and degree day models.
an asterisk have been validated for Utah.

Target Insect		Lower Developmental Threshold (F)	Upper Developmental Threshold (F)	Availability of Model
Name	Scientific Name			
eevil	*Hypera postica*	50	87	yes
n	*Pseudaletia unipuncta*	50	84	yes
worm	*Agrotis ipsilon*	50	86	yes
maggot	*Delia radicum*	40	86	yes
noth*	*Cydia pomonella*	50	88	yes
vorm*	*Helicoverpa zea*	55	92	yes
pine shoot moth	*Rhyacionia bouliana*	28	---	yes
red mite	*Panonychus ulmi*	51	---	yes
eachtree borer	*Synanthedon exitiosa*	50	87	no
borer*	*Podosesia syringae*	50	---	yes
anded leafroller*	*Choristoneura rosaceana*	43	85	yes
ig borer*	*Anarsia lineatella*	50	88	yes
a	*Cacopsylla pyricola*	41	-	no
scale*	*Quadraspidiotus perniciosus*	51	90	yes
y root weevil	*Otiorhynchus ovatus*	40	103	yes
ed cutworm	*Peridroma saucia*	45	80	yes
usk fly*	*Rhagoletis completa*	41	130	yes
herry fruit fly*	*Rhagoletis indifferens*	41	130	yes

del has been validated for Utah
und model information from: UC-Davis IPM Web site: http://www.ipm.ucdavis.edu/MODELS/index.html