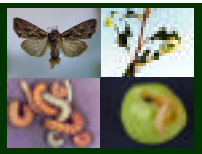

Temperature-dependent development of *Lacanobia subjuncta* (Lepidoptera: Noctuidae)

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Summary

Lacanobia subjuncta (Lepidoptera: Noctuidae) occurs throughout North America and is reported to feed on a wide variety of plants including row crops, shrubs, trees and several weed species found in orchard groundcovers. In recent years the larvae of this insect have become a troublesome pest of apples. Insecticides are the primary means to control *L. subjuncta*. While chlorpyrifos (Lorsban, organophosphate) and endosulfan (Thiodan, chlorinated hydrocarbon) control most larval stages, selective or "softer" chemicals [e.g. spinosad (Success, Naturalyte® fermentation product)] appear to be more effective against early instar larvae (Figure 1). Optimizing the application timing of "softer" insecticides is critical to maintaining control of *L. subjuncta* while promoting integrated pest management during the summer. In order to target insecticide applications for specific larval stages, we developed a degree-day model.

A model that accurately predicted phenological events and that would be useful for management decisions should be accurate to within ±3 days. Field observations of predicted data appeared to be within this acceptable margin of error (Table 5). The purpose for developing a predictive model was to aid in the timing of insecticide applications. For example, an ideal timing for optimizing the application of Success 2 SC (spinosad) would be when the majority of egg hatch was complete and most larvae were of a susceptible stage (4th instar or earlier). Our data for the first generation indicates that 80% egg hatch occurred at approximately 700 degree days from biofix (Figure 5), when the majority of larvae were still 1-3 instars. The presence of more mature 5-6 instar larvae was noted at 1000 degree days. Therefore the ideal timing for a Success application would be 700-850 degree days past biofix. The 150 degree day window provides sufficient opportunity to apply the insecticide under ideal climatic conditions.

Establishing degree day (DD) requirements

- Eggs, larvae, pupae reared at constant (10°C-37.5°C) and fluctuating temperatures.
- Newly eclosed pairs monitored for oviposition behavior in mating cages (23.3°C).
- Linear DD model parameters and estimated requirements
  - –Base temperature estimated by extrapolating linear portion of curve (Figure 2).
  - –Upper threshold of 31°C was set based on data shown in figure 2.
  - –Average lower threshold for development of eggs and larvae was 6.7°C (Table 1) and 43.5°F (Table 2).
  - –Fluctuating and constant temperature data closely correlated (Table 3). Data from table 3 generated with a linear degree day calculator.
  - –Pupae into diapause at 15°C and below (Table 3).
  - –100% larval mortality noted at 32.5°C and eggs died at 35.0°C (Table 3).
- Oviposition behavior
  - –Accurate DD requirements difficult due to only one temperature tested.
  - –Estimate of preoviposition period was 280 DD (Figure 3, Table 3).
  - –Estimate of oviposition period approximately 500-600 DD/female (Figure 3).

Table 1: Linear degree day requirements (Celsius) at constant temp.

Life stage	Equation [1]	R^2	Base T (°C)[2]	Linear DD[3]	n
Egg mass	y=0.013x-0.089	0.979	6.6	74.6	43
Larva	y=0.002x-0.014	0.936	6.7	476.2	285
Pupa	y=0.003x-0.016	1.000	4.9	312.5	111

[1] Regression model is y=mx + b, where 'y' is development rate (1/days at stage) and 'x' is temperature (°C).
[2] Base temperature for development calculated by extrapolating linear model to x-axis.
[3] Linear degree day requirements calculated as 1/slope of regression model.

Table 2: Linear degree day requirements (Fahrenheit)

Life stage	Equation [1]	R^2	Base T (°F)[2]	Linear DD[3]	n
Egg mass	y=0.007x-0.326	0.979	44.1	135.2	43
Larva	y=0.001x-0.051	0.936	42.8	833.3	285
Pupa	y=0.002x-0.073	1.000	40.4	555.5	111

[1] Regression model is y=mx + b, where 'y' is development rate (1/days at stage) and 'x' is temperature (°C).
[2] Base temperature for development calculated by extrapolating linear model to x-axis.
[3] Linear degree day requirements calculated as 1/slope of regression model.

Table 3: Linear degree day model requirements by temperature.

Temp (°C)	DD requirements at life stage [1] Preoviposition [2]	Egg	Larva	Pupa
10.0		79.8	741.0	Diapause
15.0		145.5	891.0	Diapause
20.0		124.8	708.0	492.0
25.0	240.0	132.0	851.4	511.5
30.0		155.4	949.2	625.8
32.5		198.0	Death	Death
Constant temperature				
Avg (SE)	280.0	137.1 (11.8)	874.0 (46.7)	535.8 (30.4)
Fluctuating temperature				
		130.7 (4.3)	946.9 (7.0)	492.3 (7.4)

[1] DD estimates calculated with base temperature= 7° (44°F) and upper threshold= 31°C (88°F).
[2] Preoviposition data taken at 23.3°C (74°F). Estimates at 23.3°C were about 80% that of the average for other stages, thus the 280 DD estimate.

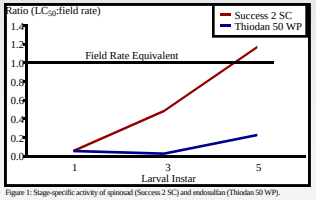

Figure 1: Stage-specific activity of spinosad (Success 2 SC) and endosulfan (Thiodan 50 WP).

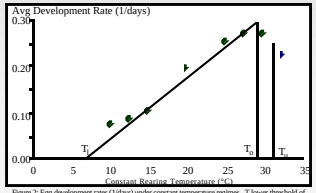

Figure 2: Egg development rates (1/days) under constant temperature regimes. T_l lower threshold of development, T_o optimal rearing temperature and T_u upper threshold for development.

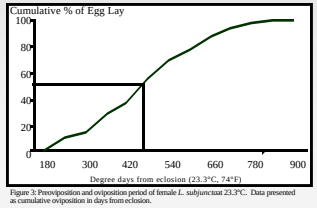

Figure 3: Preoviposition and oviposition period of female *L. subjuncta* at 23.3°C. Data presented as cumulative oviposition in days from eclosion.

Field validation of degree day (DD) model

- All field validation calculations performed with degrees Fahrenheit.
- Intensively sampled 10 orchards that varied in climatic conditions.
- Oviposition and hatch
  - –Inspected foliage, flagged egg masses and recorded date of oviposition and hatch (first generation-79 total masses).
  - –Oviposition began at 280 DD past biofix and lasted 700 DD (Figure 4).
  - –Hatch began at 400 DD past biofix.
- Larval development
  - –Monitored with limb tap and beating tray method and recorded number of each instar (2500 total larvae).
  - –First generation larvae collected at 400 DD through 1400 DD (Figure 5).
  - –Second generation larvae collected at 2250 DD through 3800 DD (Figure 6).
- Adult males
  - –Monitored with bucket-style traps baited with pheromone lures.
- Model estimates and observational validation (Table 4, subset of complete data)
  - –Compared predicted DD and calendar day estimates with observational data.
  - –First generation adults at 378 DD from 1 Mar, second generation adults at 1800 DD from biofix.
  - –Model accuracy based on the absolute value of variation from a predicted event.
  - –Predictions most accurate when a horizontal cutoff method was used.

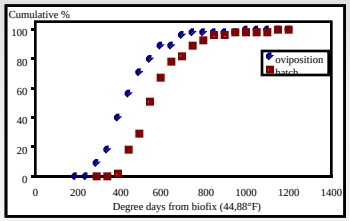

Figure 4: First generation oviposition and hatch periods of *L subjuncta* .

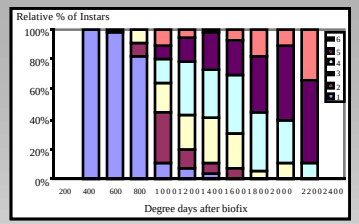

Figure 5: Relative population distribution of *L. subjuncta* larvae during the first generation as monitored by limb tapping.

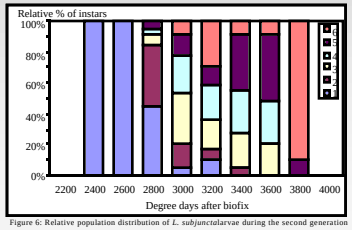

Figure 6: Relative population distribution of *L. subjuncta* larvae during the second generation as monitored by limb tapping.

Table 4: Model estimates and field validation of DD model (subset of data).

Event	Location	Degree days Predicted	Observed	|variation|	Calendar days Predicted	Observed	|variation|
First generation							
Biofix	Quincy	378	340	38	27 Apr	24 Apr	3
	Brewster		343	35	29 Apr	27 Apr	2
	Chelan		379	1	24 Apr	24 Apr	0
	Stayman		401	23	23 Apr	25 Apr	2
Avg |variation|				**24.2**			**1.8**
Oviposit	Quincy	280	280	0	19 May	19 May	0
	Brewster		287	7	22 May	22 May	0
	Chelan		311	31	20 May	20 May	2
	Stayman		319	39	20 May	20 May	2
Avg |variation|				**19.3**			**1.0**
Hatch	Quincy	415	411	4	26 May	26 May	1
	Brewster		356	59	27 May	27 May	4
	Chelan		385	30	24 May	24 May	2
	Stayman		418	3	26 May	26 May	0
Avg |variation|				**24.0**			**1.8**
Second generation							
Flight	Quincy	1800	1726	74	27 Jul	24 Jul	3
	Brewster		1780	20	1 Aug	31 Jul	1
	Chelan		1851	51	30 Jul	31 Jul	1
	Stayman		1797	3	31 Jul	31 Jul	0
Avg |variation|				**52.3**			**2.1**