Phenology/Degree-Day Model Analysis – Apr 12, 2017, updates Oct 15, 2018, Mar 7, 2019

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Small Tomato Borer/Tomato Fruit Borer *Neoleucinodes elegantalis* (Lepidoptera: Crambidae)

Hosts: Solanaceae (Tomato, eggplant, pepper; not reported as a pest of potato at least in Brazil)

Goal: Develop a phenology model and temperature-based climate suitability model using available literature and weather data analysis

Source 1. Moraes, C.. and L.A. Foerster. 2015. Thermal Requirements, fertility, and number of generations of Neoleucinodes elegantalis (Guenee)(Lepidoptera: Crambidae) Neotrop. Entomol 44:338-344.

- Studies in Brasil; Lab development 5 temperatures reared on hybrid tomato (Paronset)
- Results reported suggest ca Tlow (low threshold) of ca. 8.8C for eggs, 7.7C for larvae and pupae, and 17.5 for pre-OV. This disparity creates a problem for the simple DD model that requires a common threshold. One solution is to lean more heavily on stages taking the longest (larvae+pupae), less heavily on stages taking the shortest time (pre-OV)
- Also cooler temperatures were not tested in this study, which would be needed to reach better estimates for Tlow for each stage.
- From analysis below, where we "solved" for a best common threshold, we propose a compromise threshold of 8.9 C or 48 F. This could be rather high for eggs, only slightly high for larvae and pupae, and very low for PreOV;
- NOTE PreOV results in this study are also weakest for (only 3 temps used; the 20C point is not well lined up with the other two points, suggesting that the Tlow suggested (17.5C) may be high.

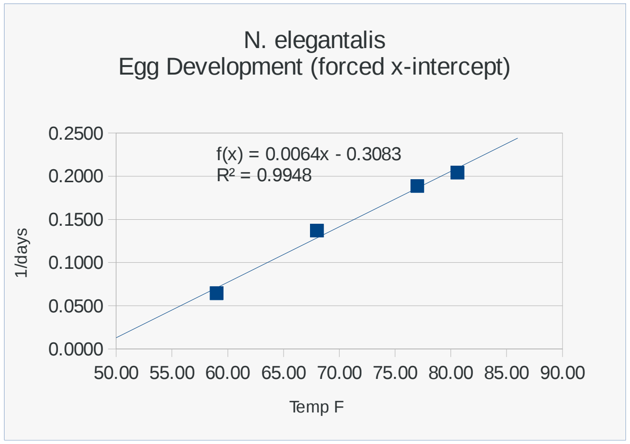
1. Re-interpret temperature vs. development rate data to solve for best overall common threshold and corresponding developmental DDs:

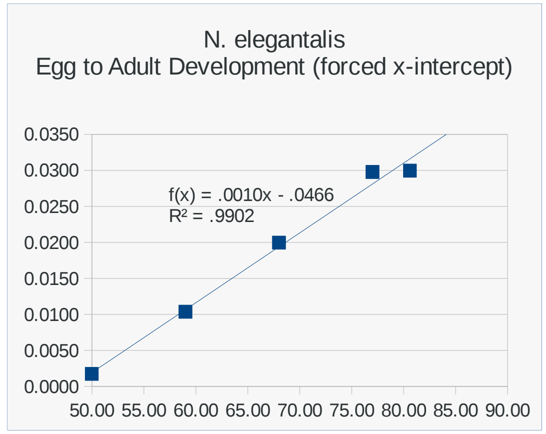
Yellow background: point added to force x-intercept (or outliers excluded)

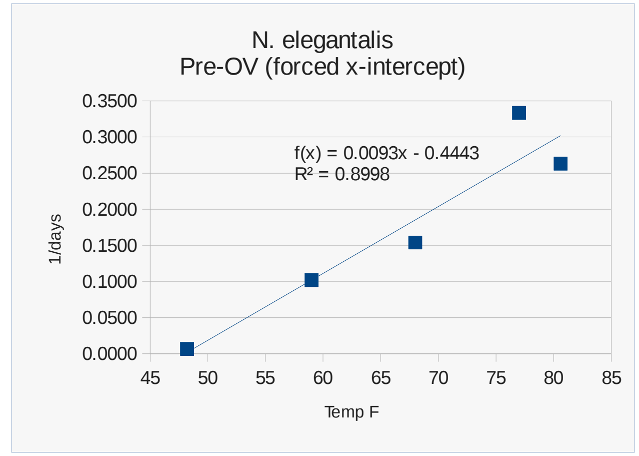
From Tables 1&3: (use the x-intercept method to find Tlow and developmental (DD) requirements for major stages):

Salmon background: most relevant results

								Devel. Rate							
	Days Development							1/days			1/days			1/days	
Temp C	Egg	Larvae	Prepupa	Pupa	Total	PreOV	Temp F	**Egg**		Temp F	**EggtoAdult**		TempF	**PreOV**	
	144				580	150	49.00	0.0069		50.00	0.0017		48.2	0.0067	
15	15.5	40.4	9.1	31.4	96.4	9.8	59.00	0.0645		59	0.0104		59.00	0.1020	
20	7.3	25.6	4.0	13.2	50.1	6.5	68.00	0.1370		68	0.0200		68.0	0.1538	
25	5.3	15.9	3.0	9.4	33.6	3	77.00	0.1887		77	0.0298		77.0	0.3333	
27	4.9	16.7	2.6	9.2	33.4	3.8	80.60	0.2041		80.6	0.0299		80.6	0.2632	
30		13.2	2.1	8.8		4.3	86.00			86					
							slope:	0.00642		slope:	0.00097		slope:	0.00926	
							intercept:	-0.30832		intercept:	-0.04657		intercept:	-0.44434	
							R-sq:	0.99482	Deg. C	R-sq:	0.99022	Deg. C	R-sq:	0.89979	Deg. C
						Tlow =	**-a/b**	**48.00**	**8.9**	**-a/b**	**48.00**	**8.9**	**-a/b**	**48.00**	**8.9**
						Dds devel	**1/slope**	**155.7**	**86**	**1/slope**	**1030.8**	**573**	**1/slope**	**108.0**	**60**







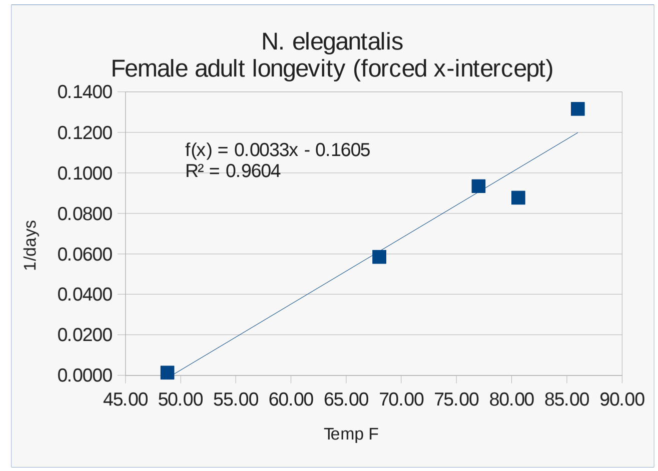
Estimated proportionate Dds Larvae and Pupae:

	Temp C	Days L	Days PP+P	Total		Prop L	Prop PP+P
	20	25.6	17.2	42.8		0.5981308	0.401869
	25	15.9	12.4	28.3		0.5618375	0.438163
	27	16.7	11.8	28.5		0.5859649	0.414035
					Avg:	0.5819777	0.418022

Results: The lower threshold of 8.889C/48F fits OK for eggs, larvae, and PreOV

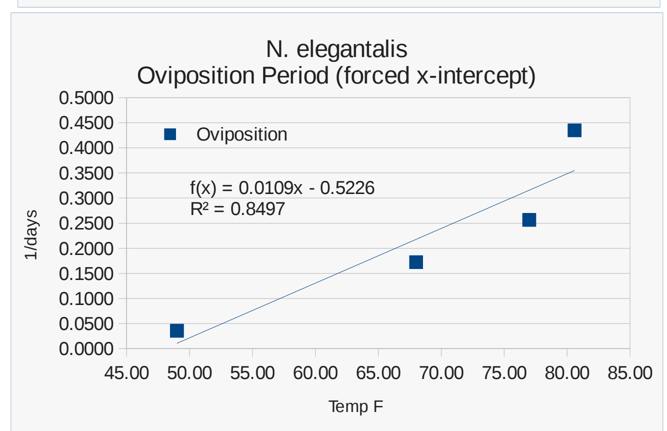
At this threshold we get the following DD requirements:

	DDsC8.9	DDsF48
Egg	**86**	**156**
Larvae	**283**	**509**
Pupae	**203**	**366**
Larvae+Pupae	**486**	**875**
Egg-Adult	**573**	**1031**
Pre-OV	**60**	**108**



2. Oviposition and adult longevity periods (from Tables 3 & 4):

					Devel. Rate			
	Days Development				**1/days**			
Temp C	**Ovipositio**	**Female Longev.**		**Temp F**	**Ovipositio**	**Temp F**	**Fem. Long.**	
	28	730		49.00	0.0357	48.80	0.0014	
15		23.8						
20	5.8	17.1		68.00	0.1724	68.00	0.0585	
25	3.9	10.7		77.00	0.2564	77.00	0.0935	
27	2.3	11.4		80.60	0.4348	80.60	0.0877	
30		7.6				86.00	0.1316	
				slope:	0.01089		0.00293	
				intercept:	-0.52265		-0.14041	
				R-sq:	0.84965	Deg. C	0.97489	Deg. C
			Tlow =	**-a/b**	**48.00**	**8.9**	**48.00**	**8.9**
			Dds devel	**1/slope**	**91.8**	**51**	**341.9**	**190**



Results: Oviposition time is rather short at only 92DDF/51DDC, especially considering that female longevity is much longer at 342DDF/190DDC. We will use 80% of this time to use for peak generation time. In addition we will use 60% of female longevity for 90% oviposition.

	DDsC8.9	DDsF48
Ovip time peak generation time	**41**	**73**
Female longevity	**190**	**342**
60% of Fem long (for 90% OV)	**142**	**205**

3. Evidence for spring activity: (need better evidence)

notes: no apparent photoperiodic response or diapause or specific overwintering stage;

Assume that reproduction is rare during the winter since hosts would be less abundant and temperatures may be slightly lower than the threshold at least in the subtropics

Source 2. Moraes, C and L.A. Foerster. 2014. Development and reproduction of Neoleucinodes elegantalis (Lepidoptera: Crambidae) on tomato (Solanum licopercum) cultivars. Rev. Columb. De Entomol. 40:40-43.

-Reared at 1 temp (20C) on 3 different tomato cultivars in S. Parana state of Brazil

From Table 1:

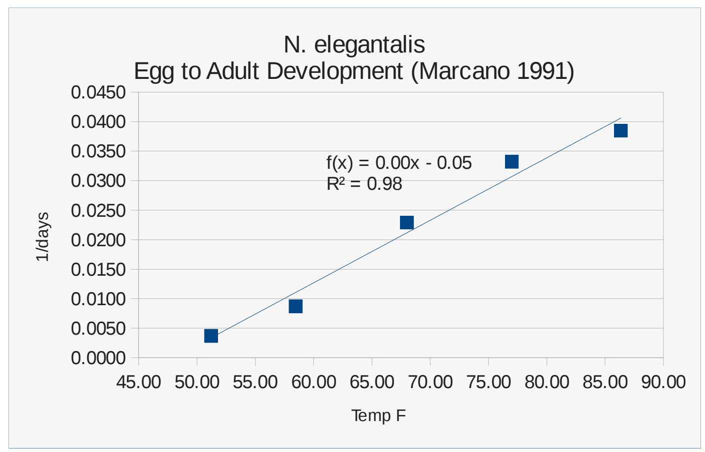
Cultivar	Temp C	Days Egg	Larvae	PP+Pupae	Total	Temp F	Est DdsF 48F Tlow Egg	Temp F	Est DdsF 48F Tlow EggtoAdult
Santa Cla	20	7.4	25.8	17	50.2	68.00	148.0	68.00	1004.0
Paronset	20	7.3	26.1	17.3	50.7	68.00	146.0	68.00	1014.0
Giuliana	20	7.4	29.5	19.3	56.2	68.00	148.0	68.00	1124.0
Average		**7.4**	**27.1**	**17.9**	**52.4**		**147.3**		**1047.3**
						Celsius:	**82**		**582**

Results: Egg development time avg. 147 vs 156 DDF48 Source #1; Total (Egg to adult) development time avg 1047 range 1004-1024 vs 1031 DDF48 Source #1.

Source 3. Marcano RV. 1991. Estudio de la biologia y algunos aspectos del comportamiento del perforador del fruto del tomate Neoleucinodes elegantalis (Lepidoptera: Pyralidae) en tomate. Agronomía Tropical. 41(5-6): 257-263.

(Data posted in other sources citing this reference; namely the EPPO PRA)

Temp C	Days Development Egg	Larvae	Pupa	Total	Temp F	Devel. Rate 1/days Egg		Temp F	1/days EggtoAdult	
11.5	150			270	52.71	0.0067		51.20	0.0037	
14.7	9.2	64.0	41.5	114.7	58.46	0.1085		58.46	0.0087	
20	7.1	22.7	13.9	43.7	68.00	0.1408		68.00	0.0229	
25	5.1	15.7	9.3	30.1	77.00	0.1961		77.00	0.0332	
30.2				26.0	86.36			86.36	0.0385	
					slope:	0.00704		slope:	0.00106	
					intercept:	-0.33809		intercept:	-0.05084	
					R-sq:	0.89583	Deg. C	R-sq:	0.97845	Deg. C
				Tlow =	**-a/b**	**48.00**	**8.9**	**-a/b**	**48.00**	**8.9**
				Dds devel	**1/slope**	**142.0**	**79**	**1/slope**	**944.1**	**525**



Results: Egg-to-adult development also resolves well using 48F Tlow, giving 944 vs 1031 DDF48 in Source #1.

4. Model Stages Summary

Species:	*Neoleucinodes elegantalis*		
Common Name & abbrev:	Small tomato borer (STB)		
Country of Origin, data from:	South and Central america; Brazil		
Pest of:	Vegetables including tomato, eggplant and peppers		
Validation Status:	Not validated; no spring activity data available to calibrate model initialization (this model is therefore conservative and may predict too early)		

	Deg.s (C)	Deg.s (F)	Notes:
Lower Threshold:	8.89	48	Best overall Tlow for all stages, Pre-OV & OV may be slightly higher
Upper Threshold:	32.22	90	High egg mortality above 30C/86F; but account for diff. in canopy temps vs weather shelters
Calculation Method:		Single Sine	
Model Start:		January 1st	Temperate adapted species OW in reproductive diapause, may become active around 12hr Daylength (ca. Mar 20)

Degree-Day Requirements	**DDs (C)**	**DDs (F)**
Egg	86	156
Larvae+pupae	486	875
Egg-to-Adult	573	1031
Pre-OV	60	108
Dds to Peak OV	101	181
Dds to 90% OV	174	313
Egg-to-1st-OV (min gen. time)	633	1139
Egg-to-Peak-OV (avg gen. time)	674	1212

5. Model Degree-Day Events Summary

	DDs (C)	DDs (F)	
First Spring Egg-Laying	60	108	Not reported; overwinter in all stages; assume earliest spring activity by adults is ca. same as Pre-OV
Peak Spring Egg-Laying	101	181	
First adults G1	633	1139	
Peak 1st Gen. Egg-Laying	774	1394	
Peak 2nd Gen. Egg-Laying	1448	2606	
Peak 3rd Gen. Egg-Laying	2121	3819	
Peak 4th Gen. Egg-Laying	2795	5031	
Peak 5th Gen. Egg-Laying	3468	6243	
Peak 6th Gen. Egg-Laying	4142	7456	
Peak 7th Gen. Egg-Laying	4816	8668	
Peak 8th Gen. Egg-Laying	5489	9880	

6. Model Degree-Day Event Ranges Summary

	Begin C	End C	Begin F	End F
OW Adults feeding on nectar and finding hos	0	100	0	180
1st Spring Egg-Laying by OW Adults	100	732	180	1318
1st Gen. Adults Egg-Laying	733	1365	1319	2457
1st and 2nd Gen. Adults	1365	1998	2458	3596
Max. 3rd Gen. Adults; Peak 2nd Gen.	1998	2630	3597	4734
Max. 4th Gen. Adults; Peak 3rd Gen.	2631	3263	4735	5873
Max. 5th Gen. Adults	3264	3896	5874	7012
Max. 6th Gen. Adults; Peak 4th Gen.	3896	4528	7013	8151
Max. 7th Gen. Adults; Peak 5th Gen.	4529	5161	8152	9290
Max. 8th Gen. Adults	5162	5794	9291	10429
Max. 9th Gen. Adults; Peak 6th Gen.	5794	6427	10430	11568
Max. 10th Gen. Adults; Peak 7th Gen.	6427	7059	11569	12707
Max. 11th Gen. Adults; Peak 8th Gen.	7060	7692	12708	13845
Max. 12th Gen. Adults	7692	8325	13846	14984
9 to 13 or more overlapping generations	8325	5556	14985	10000