Potato/Tomato psyllid **Phenology/Degree-Day Model for USPEST.ORG**

Bactericera cockerelli (Sulc) **Synthesis analysis by Len Coop, Oregon State University IPPC Jan. 25, 2017**

Data contributing most directly to model(s) with salmon background

Sources (in no particular order)

1. Munyaneze 2012 Invited Review Article **Zebra chip disease of potato: biology, epidemiology, and management. Am. J. Pot. Res. 89:329-350.**

adult longevity 20-62 days; females live 2-3 times longer than males
OV period up to 50 days; fecundity 300-500 eggs per female
5 nymphal instars
optimum development at 27C; OV, hatch, survival reduced at 32C and cease at 35C
single gen. 3-5 weeks
3-7 gens depending on climate; quickly become overlapped
cold tolerant; nymphs survive temporary exposure to -15C; 50% adults survive exposure to -10C for over 24h (Henne et al 2010)
N. America – migrate in late spring from OW and breeding areas in S. and W. Texas, Southern NM, AZ, CA, N. Mexico
Migrate to midwest states/Canada along rocky mntns
Seem to be separate Western and Central biotypes; see Liu and Trumble 2007; seems a NW biotype exists as well; Zebra Chip not yet assoc. w/ NW biotype
Females able to mate same day as eclosion; able to lay eggs 2 days after mating.
nymphs most often in middle portion of potato canopy
transmits LSO (cause of Zebra Chip) to potato within a few hours of colonizing a potato plant
seasonal arrival of PP (late June to late July) into potato but cannot be predicted year to year

refs with temperature studies: List 1939, Pletsch 1947, Wallis 1955, Cranshaw 2001, Abdullah 2008, Yang and Liu 2009 Yang et al. 2010A, Butler and Trumble 2012a

Butler, C.D., and J.T. Trumble. 2012a. The potato psyllid, Bactericera cockerelli (Sulc) (Hemiptera: Triozidae): life history, relationship to plant diseases, and management strategies.Terrestrial ArthropodReviews5: 87–111

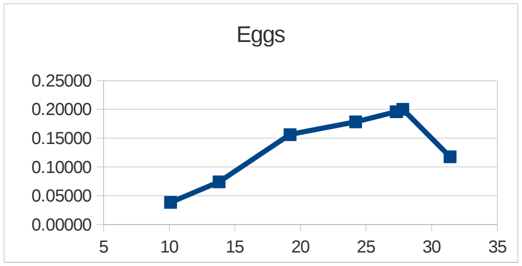
2. Lewis, O.M., G.J. Michels, E.A. Pierson, and K.M. Heinz. 2015. A predictive degree day model for the development of Bactericera cockerelli (Hemiptera: Triozidae) infesting Solanum tuberosum. Env. Entomol. 44:1201-1209.

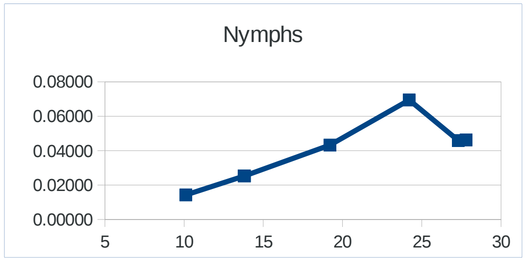
Tables 1 & 3

ranges used in regressions yellow bkgrnd

Eggs			
	Temp C	1/days	days
	10.1	0.03831	26.1
	13.8	0.07407	13.5
	19.2	0.15625	6.4
	24.2	0.17857	5.6
	27.3	0.19608	5.1
	27.8	0.20000	5.0
	31.4	0.11765	8.5
Slope =	0.01054		
Intercept =	-0.06560		
Rsq =	0.95941		
-a/B=	6.2 (estimated Tlow)		
1/slope	94.8 (DD requirement)		

Nymphs			
	Temp C	1/days	days
	10.1	0.01429	70.0
	13.8	0.02538	39.4
	19.2	0.04329	23.1
	24.2	0.06944	14.4
	27.3	0.04587	21.8
	27.8	0.04630	21.6
	31.4	#DIV/0!	
Slope =	0.00386		
Intercept =	-0.02692		





Regression forced through Tlow **4.4** C

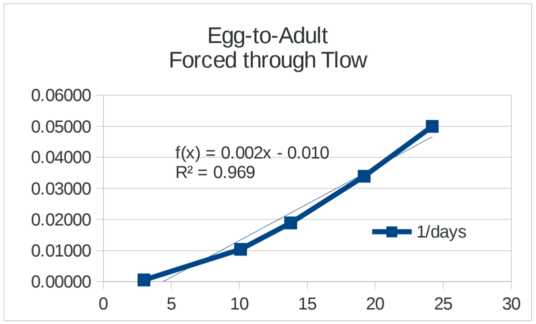
Eggs	Temp C	1/days	days
	3.7	0.00500	200
	10.1	0.03831	26.1
	13.8	0.07407	13.5
	19.2	0.15625	6.4
	24.2	0.17857	5.6
	27.3	0.19608	5.1
Slope =	0.00923		
Intercept =	-0.04061		
Rsq =	0.95978		
-a/B=	4.400 (estimated Tlow)		
1/slope	108.4 (DD requirement)		

Nymphs			
	Temp C	1/days	days
	4.1	0.00510	196
	10.1	0.01429	70.0
	13.8	0.02538	39.4
	19.2	0.04329	23.1
	24.2	0.06944	14.4
	27.3	0.04587	21.8
	27.8	0.04630	21.6
Slope =	0.00319		
Intercept =	-0.01404		

Rsq =	0.98287	
-a/B=	7.0	(estimated Tlow)
1/slope	258.8	(DD requirement)

Egg to Adult

	Temp C	1/days	days
	10.1	0.01041	96.1
	13.8	0.01887	53.0
	19.2	0.03390	29.5
	24.2	0.05000	20.0
	27.3	0.03717	26.9
	27.8	0.03759	26.6
	31.4	#DIV/0!	
Slope =	0.00282		
Intercept =	-0.01909		
Rsq =	0.99563		
-a/B=	6.8	(estimated Tlow)	
1/slope	355.1	(DD requirement)	



Rsq =	0.95096	
-a/B=	4.403	(estimated Tlow)
1/slope	313.5	(DD requirement)

Egg to Adult

	Temp C	1/days	days
	3	0.00053	1900
	10.1	0.01041	96.1
	13.8	0.01887	53.0
	19.2	0.03390	29.5
	24.2	0.05000	20.0
	27.3	0.03717	26.9
	27.8	0.03759	26.6
Slope =	0.00235		
Intercept =	-0.01036		
Rsq =	0.96945		
-a/B=	4.401	(estimated Tlow)	
1/slope	424.8	(DD requirement)	

Notes: Lethal temps (TL)estimated at: 32.2, 28.9, and 29.3C for egg, nymph, and egg-to-adult development.

TL from List 1939 estim. Between 26.7 and 32.2C

Heat sensitively seems to explain decline or absence of PP during warmer months and years.

-according to Hansen et al 2008, Lso (zebra chip) not transmitted transovarially **(**low rate only 2% is this study**)**

-Humidity not reported! Based on data RH was not limiting.

Summary: Tlow=4.4C works well; Egg stage requires ca. 108 DD; Nymphs 313 on potato

3. List, GM. 1939. The effect of Temperature upon Egg Deposition, Egg Hatch and Nymphal Development of P. cockerelli. JEE 32:30-36.

Adult OV nearly immed. At 100F egg laying is greatly retarded. At 90F lay most all eggs within 1 day. At 80F, took 1 day longer at 70F

				Estim. DDC4.4		Estim. DDC4.4	
Tables 1&2	Temp F	Temp C	Days until fi	1st OV	Days until la	Death	Notes
RH NA	60	15.6	na	na	33		
	70	21.1	4	67	22	368	
	80	26.7	3	67	18	401	
	90	32.2	6	167	7	195	high temps make adults restless and may trigger emigration to the North
	100	37.8	0	0	3	100	100F suppressed egg laying; lethal to eggs and nymphs
	Avg @ 70,80			67		384	Time to 1st OV: 67DDC; Time to Death: 384 DDC; 4.4C Tlow

Notes: data similar to Mustafa et al 2015 below; consider these a secondary data source.

Basis for upper threshold (Tupper): 30C would fit these data but consider this a nominal value

4. Mustafa, T., DR Horton, KD Swisher, RS Zack, and JE Munyaneza. 2015. Effects of Host Plant on Development and Body Size of Three Haplotypes of B. cockerelli. Environ. Entomol. 44:593-600.

- Four genetic haplotypes in N. America: including Central US, Western US, and NW US all on potato

-in NW OW on bittersweet nightshade; a major source in spring or summer of psyllids colonizing potato fields

-40% RH **(**possibly explains the very slow develment rates observed**)**

Fig 3	PreOV	Egg Devel	Nymph Deve	EggtoAdult
Days	25C	25c	25C	25C
NW potato	5	5.4	26.5	30
Western potato	4.5	6	24.5	28
Central potato	6.5	5.5	22.5	27
NW nightshade	5.5	6	27	32
Western nightshad	5.5	6	25	29
Central nightshade	14	6	23.5	29

	PreOV	Egg Devel	Nymph Deve	EggtoAdult
Est. DDs:	Tlow=4.4			
NW potato	103.0	111.2	545.9	618.0
Western pot	92.7	123.6	504.7	576.8
Central pota	133.9	113.3	463.5	556.2
NW nightsha	113.3	123.6	556.2	659.2
Western nigh	113.3	123.6	515.0	597.4
Central nigh	288.4	123.6	484.1	597.4
avg NW & W. potato:	98	117	525	597
avg NW & W. nightshade:	113	124	536	628

Notes: Nymphal development considerably slower than Wang et al above and Tran et al 2012 below
-Probably discount this study due to single (near optimal) temperature BUT suboptimal RH (40+/-5%).
-Nymphal devel slower in NW than W or Central haplotypes
-also Egg plus Nymph devel. is different from EggtoAdult devel. for some reason.

5. Tran, LT, SP Worner, RJ Hale, and DAJ Teulon. 2012. Estimating Development Rate and Thermal Requirements of B. cockerelli Reared on Potato and Tomato By Using Linear and Nonlinear Models. Environ. Entomol. 41:1190-1198.

(Laboratory studies in New Zealand; Latitude ca. 44 degrees)
-RH was 50-60%, photoperiod 16:8 L:D

Table 1
ranges used
in regressions
yellow bkgrnd
Only results from
potato used

Eggs

Temp C	1/days	Potato	Tomato
8	0.0311042	32.15	33.89
10	0.03443526	29.04	29.22
15	0.05567929	17.96	19.3
20	0.13623978	7.34	7.26
23	0.15923567	6.28	7.02
27	0.16920474	5.91	6.7
31	0.15673981	6.38	6.78

Slope =	0.01032
Intercept =	-0.07911
Rsq =	0.94666
-a/B=	7.7
1/slope	96.9

Nymphs

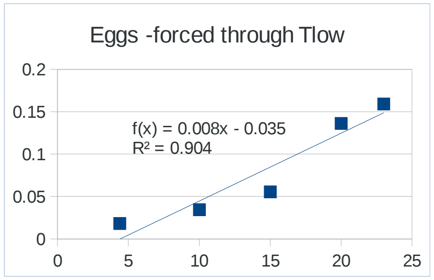
Temp C	1/days	Potato	Tomato
8	0.0171969	58.15	63.56
10	0.02625361	38.09	45.33
15	0.03443526	29.04	32.15
20	0.05216484	19.17	20.14
23	0.05934718	16.85	17.71
27	0.06565988	15.23	15.41
31	0.05227392	19.13	19.33

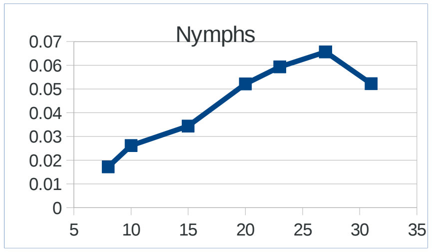
Slope =	0.00316
Intercept =	-0.01241
Rsq =	0.99074
-a/B=	3.9
1/slope	316.6

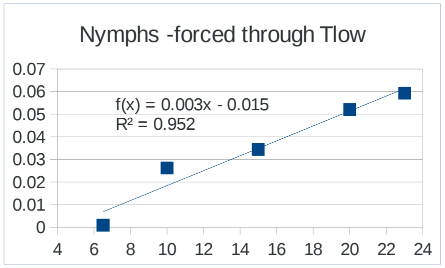
Egg-Adult

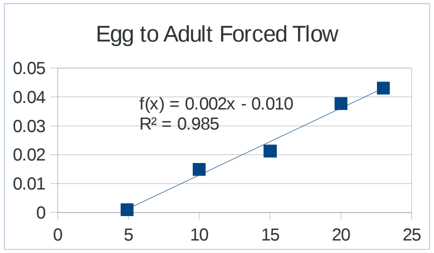
Temp C	1/days	Potato	Tomato
8	0.01107297	90.31	97.78
10	0.01489647	67.13	74.56
15	0.0212766	47	51.45
20	0.03772161	26.51	27.4
23	0.04308488	23.21	24.69
27	0.04737091	21.11	22.08
31	0.03921569	25.5	26.11

Slope =	0.00278
Intercept =	-0.01979
Rsq =	0.97996
-a/B=	7.1
1/slope	359.3









Regression forced through Tlow=4.4C

Eggs

Temp C	1/days	Potato
4.4	0.018018	55.5
10	0.034435	29.04
15	0.055556	18
20	0.13624	7.34
23	0.159236	6.28
27	0.169205	5.91
31	0.15674	6.38

Slope =	0.00801	
Intercept =	-0.03525	
Rsq =	0.90429	
-a/B=	4.402	(estimated Tlow)
1/slope	124.9	(DD requirement)

Nymphs

Temp C	1/days	Potato
6.505	0.000917	1090
10	0.026254	38.09
15	0.034435	29.04
20	0.052165	19.17
23	0.059347	16.85
27	0.06566	15.23
31	0.052274	19.13

Slope =	0.00330	
Intercept =	-0.01451	
Rsq =	0.95216	
-a/B=	4.400	(estimated Tlow)
1/slope	303.3	(DD requirement)

Egg-Adult

Temp C	1/days	Potato
4.9	0.000952	1050
10	0.014925	67
15	0.021277	47
20	0.037722	26.51
23	0.043085	23.21
27	0.047371	21.11
31	0.039216	25.5

Slope =	0.00232	
Intercept =	-0.01020	
Rsq =	0.98541	
-a/B=	4.401	(estimated Tlow)
1/slope	431.5	(DD requirement)

Notes: egg and nymphs considerably different responses; best to bias to nymphs since they take ca. 3X longer to develop; so 4-5C better than 6-7C as a common threshold
Summary: Tlow=4.4C works well; Egg stage requires ca. 124 DD; Nymphs 303 on potato

6. Yang, X.B., Y.M. Zhang, L. Hua, and T.X. Liu. 2010a. Life history and life tables of Bactericera cockerelli (Hemiptera: Psyllidae) on potato under laboratory and field conditions in the Lower Rio Grande Valley of Texas. Journal of Economic Entomology 103: 1729–1734.

Table 1	Days		Est. Dds at Tlow=4.4C			Proportionate Development Times (%)		
	Field @ 22.8	Lab @ 26.7C, 75% RH	Field	Lab	Avg	Field	Lab	Avg
Egg	6.5	4.4	119.6	98.1	108.9	28.6	22.4	25.5
L1	3.6	3.1	66.2	69.1	67.7	15.9	15.8	15.8
L2	3.6	2.4	66.2	53.5	59.9	15.9	12.2	14.1
L3	3.1	2.7	57.0	60.2	58.6	13.7	13.8	13.7
L4	3	2.7	55.2	60.2	57.7	13.2	13.8	13.5
L5	2.9	4.3	53.4	95.9	74.6	12.8	21.9	17.4
Egg-to-adult	22.4	19.6	412.2	437.1	424.6			
Egg plus Nymph Sum	22.7	19.6	417.7	437.1	427.4	100.0	100.0	100.0

7. Abdullah, NMM. 2008. Life history of the potato psyllid Bactericera cockerelli in controlled environment agriculture in Arizona. African J. Agric. Research 3:60-67.

-used 26-27C and 60-70% RH; 12:12 L:D; tomato as host plant; specimens collected from tomato greenhouses in S. AZ

-lit. review: 2H at 100F shown to be lethal to eggs and nymphs; above 90F reduces egg laying, hatching, and nymph survival;

-migration common towards north during spring and summer, facilitated by wind

							(adult-adult or PreOV+Egg+Nymph)			
Temp C	Days PreOV		Days Eggs		Days Nymphs		Days Life Cycle		Days Female Longev.	
		Dds PreOV		Dds Eggs		Dds Nymphs		Dds Life Cycle		Dds Fem. Long.
26.5	6.9	152	6.74	149	21.9	484	34.7	767	48.7	1076

8. Yang, XB, YM Zhang, DC Henne, and TX Liu. 2013. Life tables of Bactericera cockerelli on tomato under laboratory and field conditions in Southern Texas. Florida Entomol. 96:904-913.

Table 1	Days		Est. Dds at Tlow=4.4C			Proportionate Development Times (%)		
	Field 25.6C (avg)	Lab 26.7C, 75% RH	Field	Lab	Avg	Field	Lab	Avg
Egg	7.7	4.4	163.2	81.0	122.1	30.4	23.5	27.0
L1	3.4	3	72.1	55.2	63.6	13.4	16.0	14.7
L2	3.6	2	76.3	36.8	56.6	14.2	10.7	12.5
L3	3.8	2	80.6	36.8	58.7	15.0	10.7	12.9
L4	3.9	2.7	82.7	49.7	66.2	15.4	14.4	14.9
L5	3.1	4.6	65.7	84.6	75.2	12.3	24.6	18.4
Egg-to-adult	25.3	18.7	536.4	344.1	440.2			
Egg plus Nymph Sum	25.5	18.7	540.6	344.1	442.3	100.8	100.0	100.4
Fem. Adult longev.	16.2	60.5	343.4	1349.2	846.3			
PreOV	3.9	8.8	82.7	196.2	139.5			
OV period	10.5	45	222.6	1003.5	613.1			

9. Guedot, C., DR Horton, PJ Landolt. 2012. Age at reproductive maturity and effect of age and time of day on sex attraction in the potato psyllid Bactericera cockerelli. Insect Science 00:1-10.

Table 1	Fem. Age	Female age at mating + preOV @ 25C	Est. Dds at Tlow=4.4C	**Rel. Humid. Not specified**
	0	4.5	92.7	
	1	4.5	92.7	
	2	4.5	92.7	
	3	4.4	90.6	
	4	5.3	109.2	
	avg	4.64	95.6	

10. Yang, XB and TX Liu. 2009. Life history and life tables of Bactericera cockerelli on eggplant and bell pepper. Environ. Entomol. 38:1661-1667.

	Days			Est. Dds at Tlow=4.4C			Proportionate Development Times (%)		
Table 1	Eggplant	Bell pepper							
	26.7C, 70%	26.7C, 70% RH		Eggplant	Bell pepper	Avg	Eggplant	Bell pepper	Avg
Egg	5	5.9		111.5	131.6	121.5	20.7	22.5	21.6
L1	5	5.7		111.5	127.1	119.3	20.7	21.8	21.3
L2	3.2	3.1		71.4	69.1	70.2	13.3	11.8	12.6
L3	3.1	3		69.1	66.9	68.0	12.9	11.5	12.2
L4	3.2	3.1		71.4	69.1	70.2	13.3	11.8	12.6
L5	4.7	5.3		104.8	118.2	111.5	19.5	20.2	19.9
Nymphs	19.2	20.2		428.2	450.5	439.3			
Egg-to-adult	24.1	26.2		537.4	584.3	560.8			
Egg plus Nymph Sum	24.2	26.1		539.7	582.0	560.8	100.4	99.6	100.0
Tables 2 & 3									
Fem. Adult longev.	62.2	55		1387.1	1226.5	1306.8			
PreOV	8.8	8		196.2	178.4	187.3			
OV period	53.4	47		1190.8	1048.1	1119.5			

11. Notes pers. Convers. W/A. Jensen 7/12/16

-females enter winter some mated, some not, some w/developed eggs
-early OV in spring in March at budbreak of bittersweet nightshade (near Boise, ID, 2012)
Analysis: Using KBOI12.txt we get 76 DD Mar 5 and 120 DD Mar 15 and 168 CC Mar 25 (Tlow=4.4C)
-been in PNW region for decades; 2011 was outbreak year including zebra chip disease; managed/low pops since then
-NW Haplotype bigger and w/more fat reserves than other haplotypes
-Winter host (bittersweet nightshade) is frost tolerant
-Known to migrate to higher elevations in native range such as NM, AZ, W. TX, S. UT, S. Col.
-not known to have any reproductive diapause; devel. rate tied to host plant
-1 gen. in spring on nightshade; 3 or more generations on potato, then in fall 1 or 2 gen. back on nightshade
"=ca. 5-6 gen/year in pnw region
Analysis: Using KBOI12.txt and Tlow=4.4C we get 3302 DD by Nov 15; 3148 DD 2013; 3258 DD 2014; 3499 DD 2015

Year	DDC4.4	DD/678 DdperGen= approx no. generations
2012	3389	5.0
2013	3166	4.7
2014	3331	4.9
2015	3530	5.2
avg	3354	4.9

-use seed treatment neonicotinoid systemic insecticides for control; also suppresses Col. Pot. Beetle
-will apply foliar neonics when seed treatment wears out

12. S. Rondon unpublished field data 2012-2014 **(Selected Data for DD analysis)**

				Avail 2014
weather stations available:	Not adequate observed data; use PRISM interpolated data using PRISM "Data Explorer" website			
	HRMO	AGRIMET	Hermiston	YES

PRISM DATA (2012-15) matching field sampling loca

File Name	**Town**	**Lat**	**Long**	**data quant. and qual.**
PWRCTYOR	Power City	45.90399	-119.31856	v good
MCNARYOR	McNary	45.92954	-119.31358	good
STANFLDOR	Stanfield	45.77818	-119.20715	good
NA	Hat Rock	45.91354	-119.1814	fair
IRRIGONOR	Irrigon	45.89527	-119.4758	good
use STANFLDOR	cold springs	45.87686	-119.14287	good
use HRMO Agrimet	Riverfront Park			fair

POWER CITY OR Analysis

	PWRCTYOR	Count	DD4.4C	Comments
1st spring Nymphs	03/01/13	5N+0A	76	must be OW as nymphs
Zero found in samples	03/18/13	0N+0A	152	Zero at about time of estimated peak OW OV from analysis below
Next 1st spring Nymphs	04/03/13	3N+0A	241	must be OW as eggs or nymphs; Zero Adults when peak OW OV should be occuring
1st suspected F1 Adults	05/23/13	1N+3A	707	OW as nymphs or adults

Analysis: 707 – 505 (Egg+Nymph) = 202 DD possible OV

Date	DDC4.4	step:	Comments
05/23/13	707	Subt. 500 (E+N)	potential peak F1 adults
03/31/13	207		potential peak OW OV

Interpretation: within range of hypothesis that OW OV during 120-240 DD in early spring
but discount result due to low counts

MCNARY OR Analysis

	MCNARYOR	Count	DD4.4C	Comments
Zero found in samples	04/30/12	0	406	no data low population
1st suspected F1 Adults	06/08/12	7	820	Adults appear probably F1

Analysis: 820 – 505 (E+N) = 315 DD possible OV

Date	DDC4.4	step:	Comments
06/08/12	820	Subt. 500 (E+N)	potential peak F1 adults
04/23/12	320		potential peak OW OV

Interpretation: slightly later than hypothesis that OW OV during 120-240 DD in early spring
but discount results due to low counts

	MCNARYOR	Count	DD4.4C	Comments
OW Nymphs and adults	02/01/13	3N+7A	16	OW Nymphs and Adults
Zero found in samples	03/14/13	0	126	Zero at about time of estimated peak OW OV from analysis below
Zero found in samples	04/05/13	0	255	Zero at about time of estimated peak OW OV from analysis below
1st suspected F1 Adults	05/23/13	4N+17A	701	Adults appear probably F1
Zero found in samples	06/06/13	0	862	Zero soon after potential F1 peak adults – low sample counts

Analysis: 701 – 505 (E+N) = 196 DD possible OV

Date	DDC4.4	step:	Comments
05/23/13	701	Subt. 500 (E+N)	potential peak F1 adults
03/30/13	201		potential peak OW OV

Interpretation: within range of hypothesis that OW OV during 120-240 DD in early spring
but discount result due to low counts

STANFIELD OR Analysis

	STANFLDOR	Count	DD4.4	Comments
OW Nymphs	12/07/12	6	0	must be OW as nymphs
More OW Nymphs	01/01/13	6	0	must be OW as nymphs
More OW Nymphs	02/04/13	4	25	must be OW as nymphs
OW Adults highest count	01/01/13	73	0	OW Adults
Zero found in samples	03/19/13	0	163	Zero at about time of estimated peak OW OV from analysis below
Zero found in samples	04/03/13	0	249	Zero at about time of estimated peak OW OV from analysis below
1st possible F1 Adults?	05/10/13	12	550	likely OW as nymphs or are OW adults
More possible F1 Adults?	05/22/13	7	704	Potential 1st F1 adults; sufficient DDS to OW as adults

Analysis: 704 – 500 (E+N) = 204 DD possible OV

Date	DDC4.4	step:	Comments
05/22/13	704	Subt. 500 (E+N)	potential peak F1 adults
03/29/13	204		potential peak OW OV

Interpretation: supports OW OV during 120-240 DD in early spring
But counts too low after Mid Feb. to provide much confidence in this finding

OW Nymphs	12/02/13	17	0	must be OW as nymphs
More OW Nymphs	01/22/14	1	32	must be OW as nymphs
More OW Nymphs	02/21/14	1	67	must be OW as nymphs
OW Adults highest count	01/22/14	9	32	OW Adults
1st suspected F1 Adults	NA	0		
More susp. F1 Adults	NA	0		

Discontinued samples before actual F1 – last sample 5/23/14 = 695 DD

IRRIGON OR Analysis

	IRRIGONOR	Count	DD4.4	Comments
OW adults	03/22/12	4	150	OW adults: close to predicted peak OW OV
still OW adults	04/27/12	2	392	either OW adults or late stage nymphs
1st Adult uptick in counts	05/16/12	15	566	a bit too early to be F1 adults: 566-500=66 DD on Feb 26 BUT Feb22-25 all relatively warm days Tmax=11 to 17C (51-63F)

Analysis: 566 – 500 (E+N) = 66 DD possible OV? Suppose we use 480 due to “optimal conditions”

Date	DDC4.4	step:	Comments	
05/16/12	566	Subt. 480 (E+N)	potential earliest F1 adults	
03/05/12	86		potential earliest OW OV	< - This may be best data from data set for 1st OW OV

Interpretation: supports 1st OW OV during 70-90 DD in early spring — < - Also Tmax on 3/5 was 20C = 72F warmest day of year thus far

But no nymphs collected during 3 samples made during April

Next sample adult increase	05/24/12	51	659	possible Peak F1 adults from OW adults

Analysis: 659 – 500 (E+N) = 159 DD possible OV

Date	DDC4.4	step:	Comments
05/24/12	659	Subt. 500 (E+N)	potential peak F1 adults
03/25/12	159		potential peak OW OV

Interpretation: supports OW OV during 120-240 DD in early spring

Slight decrease next sample	06/14/12	21	917	
Next sample large increase	07/10/12	177	1317	Appears to be peak F2 adults

Analysis: 1317 – 691 (E+N+PreOV) = 626 DD – 505 (E+N) = 122 DD possible OW Gen OV:

Date	DDC4.4	step:	Comments
07/10/12	1317	Subt. 605 (E+N+PreOV)	Peak Sampled Adults in potato
05/29/12	712	Subt. 500 (E+N)	potential peak F1 adults
04/05/12	212		potential peak OW OV

Interpretation: supports OW OV during 120-240 DD in early spring

	IRRIGONOR	Count	DD4.4	Comments
still OW adults	02/11/13	15	36	OW Adults
still OW adults	03/14/13	10	139	either OW adults or late stage nymphs
	04/23/13	2N+0A	381	Possible F1 Nymphs
	05/09/13	8N+5A	554	Possible 1st F1 Adults

Date	DDC4.4	step:	Comments	
05/09/13	554	Subt. 480 (E+N)	potential earliest F1 adults	< - Also evidence of possible 1st OW OV
02/28/13	74		potential earliest OW OV	< - Also Tmax on 2/29 and 3/2 were 14 and 18C warmest day of year thus far

Interpretation: supports 1st OW OV during 70-90 DD in early spring — < - Note Tmin below freezing up until 2/29

With nymphs collected during 1 sample on 4/23

1st Adult uptick in counts	05/18/13	20	687	potential peak F1 OV

Date	DDC4.4	step:	Comments
05/18/13	687	Subt. 500 (E+N)	potential peak F1 adults
03/26/13	187		potential peak OW OV

Interpretation: supports OW OV during 120-240 DD in early spring

	IRRIGONOR	Count	DD4.4	Comments
still OW adults	02/26/14	0N+3A	71	either OW adults or late stage nymphs
1st Adult uptick in counts	05/12/14	3N+7A	563	likely OW as eggs or nymphs or very early F1 adults

Date	DDC4.4	step:	Comments	
05/12/14	563	Subt. 480 (E+N)	potential 1st F1 adults	< - Also evidence of possible 1st OW OV
03/06/14	83		potential 1st OW OV	< - Also Tmax on 3/5 -3/7 were 18,20, and 18C; warmest days of year thus far

Interpretation: supports 1st OW OV during 70-90 DD in early spring — < - Note Tmin below freezing on ¾ but not 3/5, 3/6 or 3/7

But no nymphs collected 4/10 or 4/25 (but present 5/12)

HAT ROCK OR Analysis – insuffcent data

COLD SPRINGS OR Analysis – Some adequate data at least for 2012

	STANFLDOR	Count	DD4.4	Comments
Single adult found	04/18/12	0N+1A	297	must be OW as nymphs or adults
Zero found in samples	04/27/12	0N+0A	392	
Next sample adult increase	05/24/12	6	650	possible F1 adults from OW adults

Analysis: 650 – 500 (E+N) = 150 DD possible OV

Date	DDC4.4	step:	Comments
05/24/12	650	Subt. 500 (E+N)	potential peak F1 adults
03/19/12	150		potential peak OW OV

Interpretation: supports OW OV during 120-240 DD in early spring

But counts low

Peak Adult next Gen? 07/10/12 89 1292 possible F1 adults from OW adults

Date	DDC4.4	step:	Comments
07/10/12	1292	Subt. 605 (E+N+PreOV)	Peak Sampled Adults in potato
05/28/12	687	Subt. 500 (E+N)	potential peak F1 adults; near match to 5/24/12 sample of 6 adults
03/30/12	187		potential peak OW OV

Interpretation: matches hypoth. Of OW OV during 120-240 DD in early spring

RIVERFRONT PARK OR Analysis – Some adequate data at least for 2013

	HRMO	Count	DD4.4	Comments
Single adult found	02/13/13	1N+1A	51	must be OW as nymphs and adults
Zero found in samples	03/19/13	0N+0A	173	Zero at about time of estimated peak OW OV from analysis below
Zero found in samples	04/03/13	0N+0A	266	Zero at about time of estimated peak OW OV from analysis below
Two adults at approx F1	05/22/13	0N+2A	733	Two adults sampled approx time expected peak F1

Analysis: 733 – 505 (E+N) = 228 DD possible OV

Date	DDC4.4	step:	Comments
05/22/13	733	Subt. 500 (E+N)	potential peak F1 adults
03/31/13	233		potential peak OW OV

Interpretation: within range of hypoth of OW OV during 120-240 DD in early spring

But counts low to provide much confidence in this finding

Overall Results (Rondon et al field data):

-Appear to OW as Adults and Nymphs and possibly eggs

-Although much of sample data has low populations, overall average matches best data results well

overall averages: OW “peak” OV: DDC4.4

	DDC4.4		
1st OV by OW females	81	from data	(three analyses above)
OW “peak” OV:	206	from data	(all analyses above except IRRIGON 2014)
F1 “peak” OV:	678	from data	(all analyses above)
OW “peak” OV from F1-50	178	from F1 data	
F2 “peak”	1305	from data	(two analyses above)
F1 “peak” OV from F2-605	700	from F2 data	
OW “peak” OV from F1-50	200	from F2 data	
AVG OW “peak” OV	195	round down to 180	
Rounded OW peak OV	190		
Rounded 1st OV	80		
Rounded 1st F1 adults	580		
Rounded Peak F1 adults	690		

- These align well with each other and with Lab tally below

13. Comparison table using DDs C (Tlow=4.4C)

Ref. No.	2	3	4	5	6	7	8	9	10	11	12		all	
Source Ref.	Lewis 2015	List 1939	Mustafa 201	Tran 2012	Yang 2010	Abdullah 20(	Yang 2013	Guedot 2012	Yang 2009	Jensen 2016	Rondon	average	**values sele**	**rationale**
Location of study	S. Texas		WA	N. Zealand	S. Texas	S. AZ	S. Texas	WA	S. Texas	OR/WA/ID	OR			
Biotype	Central		NW+W. US	Sim clim NW	Central	W. US/AZ	Central	NW	Central	NW	NW			
Host	Potato		Potato	Potato	Potato	Tomato	Tomato	Potato	eggplant	Potato/night	Potato/nightshade			
Rel. Humid.	NA		40%	55%	75%	65%	75%	NA	70%					
Eggs	108		117	125	109	149	122		112			120.3	**115**	**NW biotype**
Nymphs	314		525	303	316	484	318		426			383.7	**385**	**close to overall avg**
Egg to Adult	425		643	431	425	633	440		537			504.9	**500**	**sum of egg and nymph**
Adult Pre-OV		67	98			152	83	96	196			115.3	**105**	**avg NW biotype and overall avg**
Egg to 1st OV			741			767	523		734			691.0	**605**	**sum of egg, nymph, and pre-OV**
Fem. Adult longev.		384				1076	343		1387			797.7	**364**	**avg of List 1939 and Yang 2013**
Full gen time (E+N+Pre-OV+Adult Longev/5); use 500 for OW OV to F1 adult; use 615 for F1 adult to F2 adult												779	**678**	**sum of Pre-OV, E, N, 1/5 A longev.**
Spring/OW adults 1st OV										90	80	85.0	**90**	**from field obs**
Spring/OW adults Peak OV										170	190	180.0	**180**	**from field obs**
First F1 Adults											580		**580**	**from field obs**
Peak F1 Adults											690		**690**	**from field obs**
Peak F2 Adults											1305		**1305**	**from field obs**

Assumed unreliable: due to low humidity of study?

14. Phenology Model Version 1.0 Parameters from above:

Phenology (Degree-Day) Model:	Built for USPEST.ORG	
Common Name:	Potato psyllid	
Species:	*Bactericera cockerelli (Sulc)*	
Order and Family:	Hemiptera: Triozidae	
Pest of:	potato, tomato	
Model Sourced from studies in:	TX, WA, N. Zealand, AZ, OR, ID	
Model build for (Region):	PNW (OR, WA, ID)	
	(F)	**(C)**
Tlow:	40	4.4
Thi: (nominal)	86	30.0
Calc Method:	Single Sine or S1 (default method)	
Main Stage Development:	**DD (F)**	**DD (C)**
Egg development:	207	115
Nymphal development:	693	385
Adult Pre-OV:	189	105
OV period to peak (1/5 of total OV peri	131	73
Egg+Nymph+Pre-OV:	1089	605
Full Generation time in the field:	1220	678
Field Events:		
OW adult first OV:	162	90
OW adult peak OV:	324	180
F1 mid instar nymphs	762	423
First F1 adults	1044	580
Peak F1 adults	1242	690
F2 late instar nymphs	1873	1041
First F2 adults	1944	1080
Peak F2 adults	2348	1305
First F3 adults	2844	1580
Peak F3 adults	3568	1982
Peak F4 adults	4788	2660
Peak F5 adults	6008	3338
Peak F6 adults	7228	4016