

Spotted Wing Drosophila Degree-Day Model

Drosophila suzukii (Matsumura)

Len Coop and Amy Dreves – initial model analysis 10/14/11, revised 4/24/15 vers. 3 – Use with caution
 Integrated Plant Protection Center, Oregon State University

- Main refs:**
1. Kanzawa, T. 1939 Studies on *Drosophila suzukii* Mats., 49 pp. (translated and on file)
 2. Sakai, M. and Sato, R. 1996. Bionomics of *Drosophila pulchrella* (Diptera: Drosophilidae) Fukushima Fruit Tree Exper. Sta.
 3. Data from several sources; W. Oregon, 2009-2015 (Dreves et al.)

Addit. ref: <http://www.agri.state.id.us/Categories/PlantsInsects/RegulatedAndInvasiveInsects/Documents/2010%20Spotted%20Wing%20Drosophila.pdf>
 (citing Kanzawa 1939)

1.0 Oviposition period 10-59 days; 7-16 eggs/day (Kanzawa 1939) – assume equals ca.120 Dds required for 50% OV

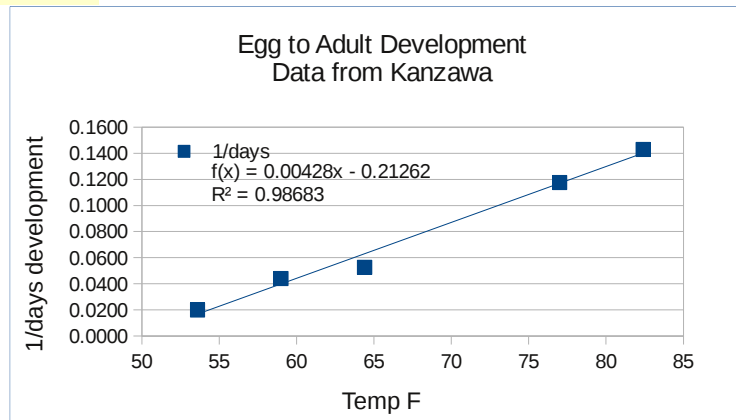
First spring oviposition expected ca mid april (Japan; Kanzawa, others) and mid May (Oregon; Dreves et al.)
 =ca. 175 Dds (same as first capture of codling moth in traps) (120 Dds is ca. 8 days at 65F constant temperature)

Max Generations	Model Version 3.0: Dds (50) F Event	Dds C
(254+50 Dds min gen time)	261 1st egg laying by OW females	144.9
2	1059 510 Peak (50%) egg laying by OW females	283.3
3	1363 510 1st adult emerge 1st gen	283.3
4	1667 565 1st egg laying by 1st gen females	313.8
5	1971 755 Peak adult emerge 1st gen	419.3
6	2275 995 Peak egg laying by 1st gen females; max 2+ gens.	552.7
7	2579 1249 Peak adult emerge 2nd gen; max 3+ gens.	693.8
8	2883 1489 Peak egg laying by 2nd gen females; max 4+ gens.	827.1
9	3187 1743 Peak adult emerge 3rd gen; max 5 gens.	968.2
10	3491 1983 Peak egg laying by 3rd gen females; max 6+ gens.	1101.6
	2237 Peak adult emerge 4th gen; max 6+ gens.	1242.7
	2477 Peak egg laying by 4th gen females; max 7+ gens.	1376.0
	2731 Peak adult emerge 5th gen; max 8+ gens.	1517.1
	3225 Peak adult emerge 6th gen females; max 9+ gens.	1791.6

2.0 Egg to Adult Development

at various temperatures:

ref above->	Temp C	Temp (F)	1/days	days
	12	53.6	0.0200	50
	18	64.4	0.0526	19
	25	77	0.1176	8.5
	28	82.4	0.1429	7
Kanzawa->	15	59	0.0441	22.7
(abstract)	model:	intercept:	-0.212619	
		slope:	0.00428	
DD requirement =		1/slope:	233.56528	
Lower dev. threshold =		X-intercept:	49.660366	
Model summary: egg to 50% OV = 254 Dds F (egg to adult) + 240 Dds (emerge to 50% OV)				
(estimate 50% OV after 8 Days at 65F=120DD)				
Total gen. Time 50% OV to 50% OV = 254+240=494 DD above 50F and below 88F				



Notes: This model analysis differs from preliminary models reported by CDFa and WSU; this and other SWD models will be updated as more lab and field data become available.

3.0 Initial Spring Emergence and Egg laying

Kanzawa reports: Activity begins early April; egg laying begins in April

4.0 Pre-Oviposition requirement (use same Tlow=50F Thi=88F)

Kanzawa 1939 – Table 6: 1 to 8 days, 2.8 avg
 Based on Table 7:
 1.2 to 7.2 days; average ca. 80+/- Dds
 44.4 Dds C

Sakai & Sato 1996		Pre-OV Period		
Temp C	Temp F	days	Dds (50)	Dds ©
18	64.4	7	100.8	56
22	71.6	4.9	105.84	58.8
25	77	3	81	45
28	82.4	4	129.6	72
		avg	104.31	57.95
		range	81 to 129	

NOTE:
USDA Corvallis observes females ovipositing within 2-3 days after emergence in lab = Use value of 50 DDs F (27.8 DD C)
for pre-oviposition period

5.0 Oviposition Schedule (again Tlow=50 Thi=88F)

Kanzawa 1939 -Table 10
 Oviposition period range 10-59 days avg=38.9 days at avg Temp=68.6 F
 $38.9 \times (68.6-50) = 723.54$ Dds (50) '= maximum (1) oviposition
 Assume w/mortality and left-skewed OV schedule; 50% of eggs deposited within 1/3 of this interval = 241 DDs (50)

Use 240 Dds for Emerge to 50% OV in model (further analysis below)

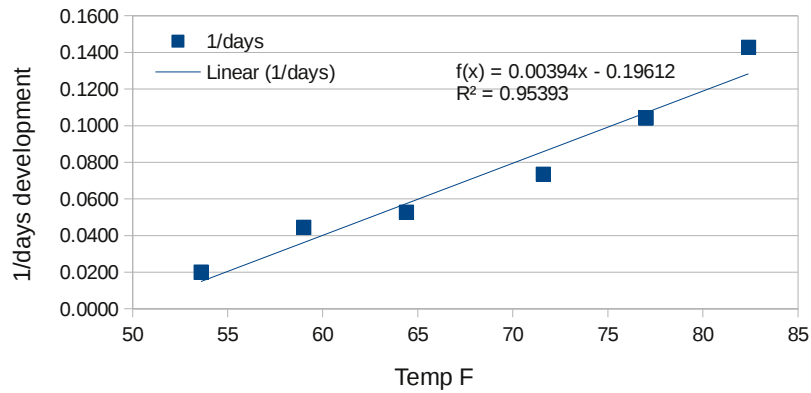
6.0 Temperature- Development of each life stage

Studies Combined						Studies Compared					
Egg to Adult Development at various temperatures:						Egg to Adult Development at various temperatures:					
	Temp C	Temp (F)	1/days	days	Lowest CV (check only) Dds (50) Dds (48)	Temp C	Temp (F)	Kanz	Sak&Sat	days	
Kanzawa->	12	53.6	0.0200	50		Kanzawa->	12	53.6	0.0200	50	
	18	64.4	0.0526	19	273.6	311.6	18.2	64.76	0.0532	18.8	
	25	77	0.1042	9.6	259.2	278.4	25	77	0.1176	8.5	
	28	82.4	0.1429	7	226.8	240.8	28	82.4	0.1429	7	
	15	59	0.0444	22.5	202.5	247.5	15	59	0.0435	23	
Sak&Sat->	18	64.4	0.0526	19	273.6	311.6	Sak&Sat	17.9	64.22	0.0518	19.3
	22	71.6	0.0735	13.6	293.76	320.96	22	71.6	0.0735	13.6	
	25	77	0.1042	9.6	259.2	278.4	25	77	0.1042	9.6	
exclude->	28		0.1042	9.6			28	82.4	0.1042	9.6	
Kyokai 2003	'->this study is somewhat unclear but generally confirms development rates to be same as Kanzawa at 15 and 25 C 'e. g. "duration from oviposition to emerg. Is short like over 20 days at 15C or about 10 days at 25C"										
model:	intercept:	-0.196	mean	255.522857	284.18	model:	intercept:	-0.213	-0.209		
	slope:	0.00394	stdev	31.0352325	32.0170392135		slope:	0.00429	0.0040		
DD requirement =	1/slope:	253.95406	CV	12.1457755	11.2664646398	DD requirement =	1/slope:	233.2328	248.249		
Lower dev. threshold =	X-intercept:	49.805341				Lower dev. threshold =	X-intercept:	49.75814	51.9482		
	Rsq:	0.95393					Rsq:	0.98531	0.9653		

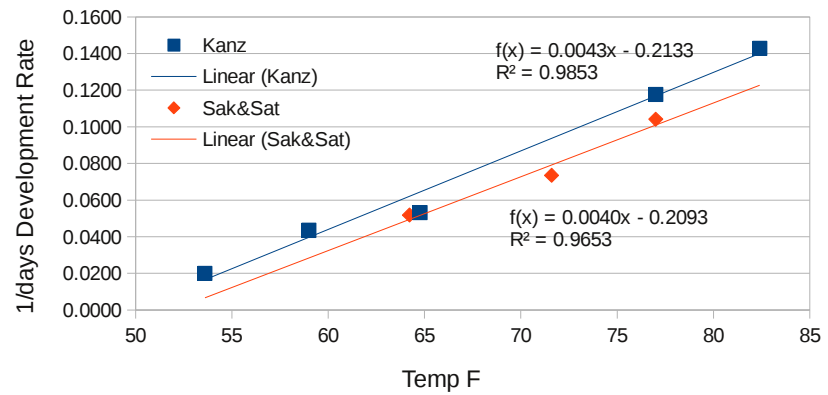
Combined Model (exclude Sakai & Sato 82.4 F data point)

Separate Models (exclude Sakai & Sato 82.4 F data point)

Egg to Adult Development
Kanzawa + Sakai and Sato data (combined)



Egg to Adult Development
Kanzawa + Sakai & Sato Data (compared)



Revised model summary: Egg-Adult Devel = 254 DD above 50F and below 88F

7.0 Proportionate development Egg/Larval/Pupal

Kanzawa (Tables 16 & 17)

Days at

	15 C	Proportion	25 C	Proportion	Avg	Dds (50)
Egg	1.8	7.8	0.5	5.7	6.7	
Larval	11.1	47.2	4.5	46.8	47.0	
Pupal	10.5	44.9	4.5	47.6	46.3	
Total	23.5	100.0	9.5	100.0	100.0	

Development requirements: Egg=17 Dds, Larvae=125 Dds, Pupae=112 Dds

Check

	Values to Use	Dds (50) 15C only	DDs (50) 25C only
17.1	17	19.821748	14.3774
119.4	125	120.01365	118.746
117.5	112	114.16461	120.876
254.0	254	254	254

254 ← check

6. Model Revision using field data from Dreves et al. 2010-2011:

changes list: 1. 1st egg laying derived from 1st gen adult 1st and peak emergence

Reference Stage Durations

Stage	DD F	DD C
Gen 1 egg	17	9.4
larvae	125	69.4
pupae	112	62.2
total e2a	254	141.1
Pre-OV	50	27.8 <-also mating,host finding
total e2ov	304	168.9
Em2_50% OV	240	133.3
Gen 2 egg	17	9.4
larvae	125	69.4
pupae	112	62.2
total e2a	254	141.1
Pre-OV	50	27.8 <-also mating,host finding
Em2_50% OV	240	133.3
Gen 3 egg	17	9.4
larvae	125	69.4

pupae	112	62.2
total e2a	254	141.1
Pre-OV	50	27.8 <-also mating,host finding
Em2_50% OV	240	133.3

Willamette Valley Oregon Trapping Data					Best date	Best cum.	Event Name	Other weather stations Willamette Valley (Dds C)						
					est	Dds C		Eugene	Aurora	Forest Gr	McMinnevil	Hillsboro apt		
2010	Year	DD C	Fly Total	Avg	% female			KEUG	ARAO	FOGO	KMMV	KHIO	Average	
						05/16/10	140.9 1 st egg laying by Ow females	161.8889	195.889	169.889	138.8889	143.88889	158.55556	
	6/24/2010	285	1	0.02	1	06/22/10	274.2 Peak (50%) egg laying by OW females	295.2222	329.222	303.222	272.2222	277.22222	291.88889	
	7/1/2010	335	26	0.57	0.42	06/23/10	282.0 1 st adult emerge 1 st gen	303	337	311	280	285	299.66667	
	7/8/2010	395	91	2.33	0.2	07/10/10	415.3 Peak adult emerge 1 st gen	436.3333	470.333	444.333	413.3333	418.33333	433	
	7/15/2010	465	58	1.49	0.33	06/27/10	309.8 1 st egg laying by 1 st gen females	330.7778	364.778	338.778	307.7778	312.77778	327.44444	
	7/22/2010	515	54	1.38	0.41	07/25/10	548.7 Peak egg laying by 1 st gen females	569.6667	603.667	577.667	546.6667	551.66667	566.33333	
	7/29/2010	590	202	5.05	0.3	07/14/10	450.9 1 st adult emerge 2 nd gen	471.8889	505.889	479.889	448.8889	453.88889	468.55556	
	8/5/2010	649	247	5.88	0.4	07/17/10	478.7 1 st egg laying by 2 nd gen females	499.6667	533.667	507.667	476.6667	481.66667	496.33333	
	8/12/2010	705	691	16.45	0.37	08/10/10	689.8 Peak adult emerge 2nd gen	710.7778	744.778	718.778	687.7778	692.77778	707.44444	
	8/19/2010	780	1116	25.36	0.37	08/24/10	823.1 Peak egg laying by 2nd gen females	844.1111	878.111	852.111	821.1111	826.11111	840.77778	
	8/26/2010	840	1361	28.96	0.39	08/02/10	619.8 1 st adult emerge 3 rd gen	640.7778	674.778	648.778	617.7778	622.77778	637.44444	
	9/2/2010	885	1103	22.98	0.39	08/05/10	647.6 1 st egg laying by 3 rd gen females	668.5556	702.556	676.556	645.5556	650.55556	665.22222	
	9/9/2010	925	1164	24.25	0.36	09/15/10	964.2 Peak adult emerge 3rd gen	985.2222	1019.22	993.222	962.2222	967.22222	981.88889	
	9/16/2010	979	1297	27.6	0.35	10/06/10	1097.6 Peak egg laying by 3 rd gen females	1118.556	1152.56	1126.56	1095.556	1100.5556	1115.2222	
	9/29/2010	1065	4154	88.38	37	08/20/10	788.7 1 st adult emerge 4 th gen	809.6667	843.667	817.667	786.6667	791.66667	806.33333	
	10/6/2010	1100	7046	153.74	39	08/24/10	816.4 1 st egg laying by 4 th gen females	837.4444	871.444	845.444	814.4444	819.44444	834.11111	
	10/13/2010	1130	11247	229.53	38	none	1238.7 Peak adult emerge 4 th gen	1259.667	1293.67	1267.67	1236.667	1241.6667	1256.3333	
	10/20/2010	1150	15795	329.06	40									
	10/27/2010	1162	16661	347.1	39									
	11/3/2010	1180	52760	1146.96	39									
2011	Year	DD 10C Jan	Fly Total	Avg	% female	Best date	Best cum.	Other weather stations Willamette Valley (Dds C)						
						Date	Dds C	KEUG	ARAO	FOGO	KMMV	KHIO	Average	
	6/21/2011	240	94	1.38	0.84	06/04/11	148.9 1 st egg laying by Ow females	156.8889	172.889	157.889	136.8889	124.88889	149.72222	
	6/28/2011	285	49	0.73	0.80	06/28/11	282.2 Peak (50%) egg laying by OW females	290.2222	306.222	291.222	270.2222	258.22222	283.05556	
	7/5/2011	338	51	0.75	0.35	06/29/11	290.0 1 st adult emerge 1 st gen	298	314	299	278	266	290.83333	
	7/12/2011	388	115	1.88	0.41	07/18/11	423.3 Peak adult emerge 1 st gen	431.3333	447.333	432.333	411.3333	399.33333	424.16667	
	7/19/2011	435	177	2.64	0.23	07/03/11	317.8 1 st egg laying by 1 st gen females	325.7778	341.778	326.778	305.7778	293.77778	318.61111	
	7/26/2011	496	271	4.37	0.37	08/01/11	556.7 Peak egg laying by 1st gen females	564.6667	580.667	565.667	544.6667	532.66667	557.5	
	8/3/2011	577	518	7.61	0.45	07/23/11	458.9 1 st adult emerge 2 nd gen	466.8889	482.889	467.889	446.8889	434.88889	459.72222	
	8/9/2011	630	1337	19.38	0.37	07/25/11	486.7 1 st egg laying by 2 nd gen females	494.6667	510.667	495.667	474.6667	462.66667	487.5	
	8/16/2011	689	1930	27.97	0.33	08/17/11	697.8 Peak adult emerge 2 nd gen	705.7778	721.778	706.778	685.7778	673.77778	698.61111	
	8/23/2011	778	1869	28.75	0.43	08/29/11	831.1 Peak egg laying by 2nd gen females	839.1111	855.111	840.111	819.1111	807.11111	831.94444	
	8/30/2011	843	2030	28.1	0.44	08/09/11	627.8 1 st adult emerge 3 rd gen	635.7778	651.778	636.778	615.7778	603.77778	628.61111	
	9/6/2011	907	3663	50.18	0.42	08/12/11	655.6 1 st egg laying by 3 rd gen females	663.5556	679.556	664.556	643.5556	631.55556	656.38889	
	9/13/2010	985	2842	39.47	0.48	09/12/11	972.2 Peak adult emerge 3rd gen	980.2222	996.222	981.222	960.2222	948.22222	973.05556	
	9/20/2010	1035	7285	101.18	0.24	09/30/11	1105.6 Peak egg laying by 3 rd gen females	1113.556	1129.56	1114.56	1093.556	1081.5556	1106.3889	
	9/27/2011	1090	10708	150.82	0.35	08/26/11	796.7 1 st adult emerge 4 th gen	804.6667	820.667	805.667	784.6667	772.66667	797.5	
						08/28/11	824.4 1 st egg laying by 4 th gen females	832.4444	848.444	833.444	812.4444	800.44444	825.27778	
						none	1246.7 Peak adult emerge 4 th gen	1254.667	1270.67	1255.67	1234.667	1222.6667	1247.5	

Model Version 3.0 – subset of all events		
	DDs (50F)	DDs (10C) Event(s)
1	261	145 1st egg laying by OW females
2	510	283 Peak (50%) egg laying by OW females
3	510	283 1st adult emerge 1st gen
4	565	314 1st egg laying by 1st gen females
5	755	419 Peak adult emerge 1st gen
6	995	553 Peak egg laying by 1st gen females; max 2+ gens.
7	1249	694 Peak adult emerge 2nd gen; max 3+ gens.
8	1489	827 Peak egg laying by 2nd gen females; max 4+ gens.
9	1743	968 Peak adult emerge 3rd gen; max 5 gens.
10	1983	1102 Peak egg laying by 3rd gen females; max 6+ gens.
11	2237	1243 Peak adult emerge 4th gen; max 6+ gens.
12	2477	1376 Peak egg laying by 4th gen females; max 7+ gens.
13	2731	1517 Peak adult emerge 5th gen; max 8+ gens.
14	3225	1792 Peak adult emerge 6th gen females; max 9+ gens.

	total	50% OV
	# gens	DD F DD C
ow gen	501	278
1 gen	755	419
2 gen	1059	588
3 gen	1363	757
4 gen	1667	926
5 gen	1971	1095
6 gen	2275	1264
7 gen	2579	1433
8 gen	2883	1602
9 gen	3187	1771
10 gen	3491	1939
11 gen	3795	2108
12 gen	4099	2277
13 gen	4403	2446
14 gen	4707	2615
15 gen	5011	2784
16 gen	5315	2953
17 gen	5619	3122
18 gen	5923	3291

Use for Color Table:

DD F	DD F
0	230 Pre-egg laying activity
231	500 Egg laying by OW females
501	995 1st gen. emergence
996	1490 2nd gen. emergence
1491	1985 3rd gen. emergence
1986	2480 4th gen. emergence
2481	2975 5th gen. emergence
2976	3470 6th gen. emergence
3471	3965 7th gen. emergence
3966	4460 8th gen. emergence
4461	4955 9th gen. emergence
4956	5450 10th gen. emergence
5451	5945 11th gen. emergence
5946	6440 12th gen. emergence
6441	6935 13th gen. emergence
6936	7430 14th gen. emergence
7431	7925 15th gen. emergence
7926	8420 16th gen. emergence

Corvallis 1971-2000 Use Corvallis as best representative of fruit growing areas in W. Valley

Normals	Average	Best cum.
DDs (50) F	Date	Dds (10) C
261	05/18/00	144.9 1st egg laying by OW females
501	06/14/00	278.2 Peak (50%) egg laying by OW females
515	06/15/00	286.0 1st adult emerge 1st gen
755	07/04/00	419.3 Peak adult emerge 1st gen
565	06/19/00	313.8 1st egg laying by 1st gen females
995	07/19/00	552.7 Peak egg laying by 1st gen females; max 2+ gens.
819	07/08/00	454.9 1st adult emerge 2nd gen
869	07/11/00	482.7 1st egg laying by 2nd gen females
1249	08/02/00	693.8 Peak adult emerge 2nd gen; max 3+ gens.
1489	08/16/00	827.1 Peak egg laying by 2nd gen females; max 4+ gens.
1123	07/26/00	623.8 1st adult emerge 3rd gen
1173	07/29/00	651.6 1st egg laying by 3rd gen females
1743	08/31/00	968.2 Peak adult emerge 3rd gen; max 5 gens.
1983	09/17/00	1101.6 Peak egg laying by 3rd gen females; max 6+ gens.
1427	08/12/00	792.7 1st adult emerge 4th gen
1477	08/15/00	820.4 1st egg laying by 4th gen females
2237	10/14/00	1242.7 Peak adult emerge 4th gen; max 6+ gens.
2477	none	1376 Peak egg laying by 4th gen females; max 7+ gens.
2731	none	1517.1 Peak adult emerge 5th gen; max 8+ gens.
2971	none	1650.4 Peak egg laying by 5th gen females; max 9+ gens.
3225	none	1791.6 Peak adult emerge 6th gen females; max 9+ gens.
3465	none	1924.9 Peak adult emerge 7th gen females; max 11+ gens.
3719	none	2066.0 Peak adult emerge 8th gen females; max 13+ gens.
3959	none	2199.3 Peak adult emerge 9th gen females; max 14+ gens.
4213	none	2340.4 Peak adult emerge 10th gen females; max 16+ gens.
4453	none	2473.8 Peak adult emerge 11th gen females; max 18 gens.

Dds C Dds (F)
Average

154.1	277.45
287.5	517.45
295.3	531.45
428.6	771.45
323.0	581.45
561.9	1011.45
464.1	835.45
491.9	885.45
703.0	1265.45
836.4	1505.45
633.0	1139.45
660.8	1189.45
977.5	1759.45
1110.8	1999.45
801.9	1443.45
829.7	1493.45
1251.9	2253.45
1385.25	2493.45
1526.3611	2747.45
1659.6944	2987.45

total (cont.)

# gens	DD F	DD C
18 gen	5923	3290.5556
19 gen	6227	3459.4444
20 gen	6531	3628.3333
21 gen	6835	3797.2222
22 gen	7139	3966.1111
23 gen	7443	4135

4707	none	2614.9	Peak adult emerge 12 th gen females
4947	none	2748.2	Peak adult emerge 13 th gen females
5201	none	2889.3	Peak adult emerge 14 th gen females
5441	none	3022.7	Peak adult emerge 15 th gen females

7. Detailed Analysis 2 – Estimation of 50% Oviposition in Dds base 50

Model of Oviposition Schedule based on Kanzawa – Table 10

Generation	1935 OV Period Days	Cum Days (68.6 avg)	Dds	OV	Cum OV	Dds	Cum Percent	Hybrid Estimate
1	26	0	0	1	1	0	0.34965	5.74
2	10	5.37634409	100	45	46	100	16.0839	20.74
3	25	10.7526882	200	60	106	200	37.0629	35.74
4	25	16.1290323	300	55	161	300	56.2937	50.74
5	42	21.5053763	400	50	211	400	73.7762	73.8932
6	50	26.8817204	500	35	246	500	86.014	84.006
7	59	32.2580645	600	25	271	600	94.7552	92.2689
8	52	37.6344086	700	15	286	700	100	99.255
9	45							
10	55							
				total	286			

50% OV est ca 240 Dds F (133.3 C)

(do not use higher values because of 1) mortality increases over time, 2) OV rate will increase with host fruit ripening)

Oviposition Models:

avg 38.9
range 10 to 59 days

DDs (50)

	Linear Model Percent OV	Log Model Percent OV	Hybrid Model Percent OV
0	5.74		5.74
50	13.24		13.24
100	20.74	11.0663128	20.74
150	28.24	29.4419915	28.24
200	35.74	42.4797431	35.74
250	43.24	52.5926088	43.24
300	50.74	60.8554218	50.74
350	58.24	67.8415306	58.24
400	65.74	73.8931733	73.893173
450	73.24	79.2311005	79.2311
500	80.74	84.006039	84.006039
550	88.24	88.3254964	88.325496
600	95.74	92.268852	92.268852
650	103.24	95.8963875	95.896387
700	110.74	99.2549608	99.254961

using avg Temp = 68.6 F

Use 240 Dds

As 50% ov

switch pt->

SWD Oviposition Model

Kanzawa Data Hybrid model

