

Spotted Wing Drosophila Degree-Day Model

***Drosophila suzukii* (Matsumura)**

Len Coop and Amy Dreves – model analysis Oct 14, 2011 version 2 – 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* Tan, Hsu et Sheng (Diptera: Drosophilidae) in Fukushima Prefecture. Fukushima Fruit Tree Exper. Sta.
 3. Data from several sources; W. Oregon, 2009-2011 (Dreves et al.)

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

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.)

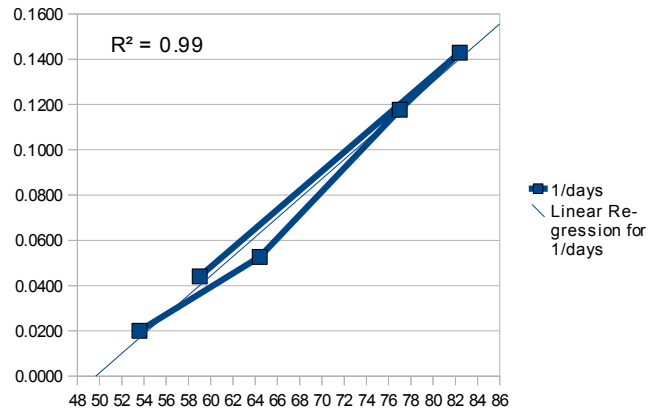
=ca. 175 Dds (same as first capture of codling moth in traps) (120 Dds is ca. 8 days at 65F constant temperature)

Egg to Adult Development at various temperatures:

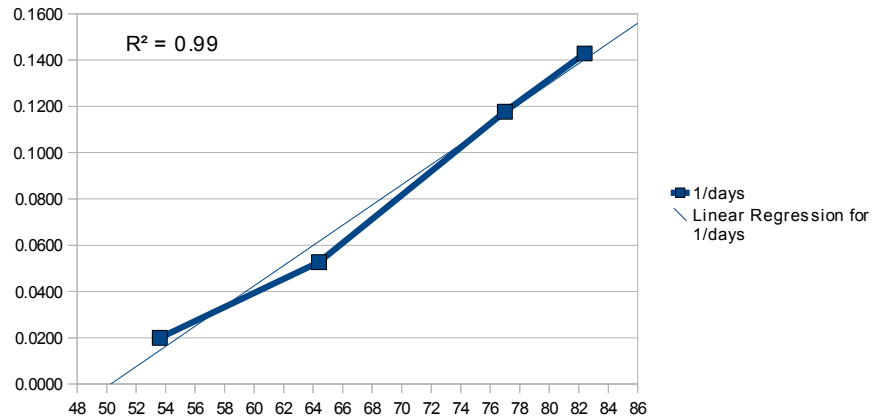
Model Version 2.0:		Dds		Temp C		Temp (F)		1/days		days	
Max Generations	Dds	Event	Dds C	ref above->	12	53.6	0.0200	50			
(254+50 Dds min gen time)		261 1st egg laying by OW females	144.89		18	64.4	0.0526	19			
2	819	501 Peak (50%) egg laying by OW females	278.22		25	77	0.1176	8.5			
3	1123	515 1st adult emerge 1st gen	286		28	82.4	0.1429	7			
4	1427	565 1st egg laying by 1st gen females	313.78	Kanzawa->	15	59	0.0441	22.7			
5	1731	755 Peak adult emerge 1st gen	419.33	(abstract)	model: intercept: -0.21						
6	2035	995 Peak egg laying by 1st gen females; max 2+ gens	552.67		slope: 0.00428						
7	2339	1249 Peak adult emerge 2nd gen; max 3+ gens.	693.78	DD requirement =	1/slope: 233.57						
8	2643	1489 Peak egg laying by 2nd gen females; max 4+ gen	827.11	Lower dev. threshold =	X-intercept: 49.66						
9	2947	1743 Peak adult emerge 3rd gen; max 5 gens.	968.22	Model summary: egg to 50% OV = 254 Dds (egg to adult) + 133 Dds (emerge to 50% OV)							
10	3251	1983 Peak egg laying by 3rd gen females; max 6+ gens.	1101.56	(estimate 50% OV after 8 Days at 65F=120DD)							
		2237 Peak adult emerge 4th gen; max 6+ gens.	1242.67	Total gen. Time 50% OV to 50% OV = 254+240=494 DD above 50F and below 88F							
		2477 Peak egg laying by 4th gen females; max 7+ gens.									
		2731 Peak adult emerge 5th gen; max 8+ gens.									
		2971 Peak egg laying by 5th gen females; max 9+ gens.									

Assume 20 Dds after emergence required for initial oviposition

Graph with Kanzawa (59F) data point:



Graph w/o Kanzawa data point:



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.

1. Initial Spring Emergence and Egg laying

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

Uchino 2005: Adult emergence observed April 23 2003 (Kisarazu City, Chiba, Japan) – calculated from data to be 250 Dds

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

Kanzawa 1939 – Analysis below
Based on Table 7:
1.2 to 7.2 days; average 80+/- Dds

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	
			50	27.78
			40	22.22

NOTE:

USDA Corvallis observes females ovipositing within 2-3 days after emergence in lab = Use value of 50 Dds F for pre-oviposition period

3. 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

$38.9 \times (68.6 - 50) = 723.54 \text{ Dds (50)}$ '= 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

4. Temperature- Development of each life stage

Studies Combined

Egg to Adult Development at various temperatures:

Lowest CV (check only)

Studies Compared

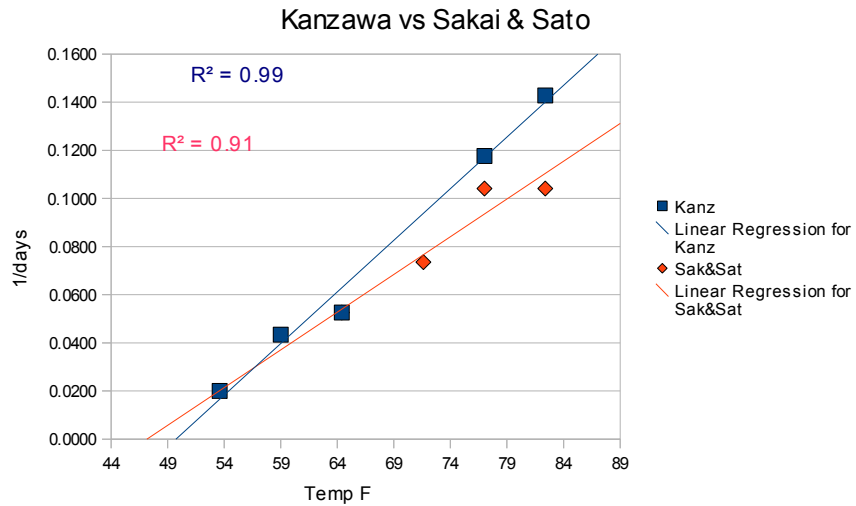
Egg to Adult Development at various temperatures:

	Temp C	Temp (F)	1/days	days	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	64.4	0.0526		19
	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	18	64.4		0.0526	19
	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	255.52	284.18	model:	intercept:	-0.213	-0.148
	slope:	0.00394 stdev	31.04	32.02		slope:	0.00429	0.0031
DD requirement =	1/slope:	253.95 CV	12.15	11.27	DD requirement =	1/slope:	233.12	319.08
Lower dev. threshold =	X-intercept:	49.81			Lower dev. threshold =	X-intercept:	49.72	47.17
	Rsqr:	0.95393				Rsqr:	0.98728	0.9139



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

5. Proportionate development Egg/Larval/Pupal

Kanzawa (Tables 16 & 17)

Check

Days at

	15 C	Proportion	25 C	ProporticAvg	Dds (50)	Values to Use	Dds (50) 15C only	DDs (50) 25C only	
Egg	1.83	7.8	0.54	5.66	6.73	17.1	17	19.82	14.38
Larval	11.08	47.25	4.46	46.75	47	119.38	125	120.01	118.75
Pupal	10.54	44.95	4.54	47.59	46.27	117.52	112	114.16	120.88
Total	23.45	100	9.54	100	100	254	254	254	254

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

254 ←check

6. Model Revision using field data from Dreves et al. 1010-2011:

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

Reference Stage Durations

Stage	deg F	deg C
Gen 1 egg	17	9.44
larvae	125	69.44
pupae	112	62.22
total e2a	254	141.11
Pre-OV	50	27.78 ←-also mating,host finding
total e2ov	304	168.89
Em2_50% OV	240	133.33
Gen 2 egg	17	9.44
larvae	125	69.44
pupae	112	62.22
total e2a	254	141.11
Pre-OV	50	27.78 ←-also mating,host finding
Em2_50% OV	240	133.33
Gen 3 egg	17	9.44
larvae	125	69.44

pupae	112	62.22
total e2a	254	141.11
Pre-OV	50	27.78 <-also mating,host finding
Em2_50% OV	240	133.33

Willamette Valley Oregon Trapping Data					Event Name	Other weather stations Willamette Valley (Dds C)					
Year	DD C	Fly Total	Avg% female	Best date est	Best cum. Dds C	Eugene KEUG	Aurora ARAO	Forest FOGO	GrMcMinnevil KMMV	Hillsboro KHIO	Average
2010											
6/24/2010	285	1	0.02	05/16/10	140.89 1 st egg laying by Ow females	161.89	195.89	169.89	138.89	143.89	158.56
7/1/2010	335	26	0.57	06/22/10	274.22 Peak (50%) egg laying by OW female	295.22	329.22	303.22	272.22	277.22	291.89
7/8/2010	395	91	2.33	06/23/10	282 1 st adult emerge 1 st gen	303	337	311	280	285	299.67
7/15/2010	465	58	1.49	07/10/10	415.33 Peak adult emerge 1 st gen	436.33	470.33	444.33	413.33	418.33	433
7/22/2010	515	54	1.38	06/27/10	309.78 1 st egg laying by 1 st gen females	330.78	364.78	338.78	307.78	312.78	327.44
7/29/2010	590	202	5.05	07/25/10	548.67 Peak egg laying by 1 st gen females	569.67	603.67	577.67	546.67	551.67	566.33
8/5/2010	649	247	5.88	07/14/10	450.89 1 st adult emerge 2 nd gen	471.89	505.89	479.89	448.89	453.89	468.56
8/12/2010	705	691	16.45	07/17/10	478.67 1 st egg laying by 2 nd gen females	499.67	533.67	507.67	476.67	481.67	496.33
8/19/2010	780	1116	25.36	08/10/10	689.78 Peak adult emerge 2 nd gen	710.78	744.78	718.78	687.78	692.78	707.44
8/26/2010	840	1361	28.96	08/24/10	823.11 Peak egg laying by 2 nd gen females	844.11	878.11	852.11	821.11	826.11	840.78
9/2/2010	885	1103	22.98	08/02/10	619.78 1 st adult emerge 3 rd gen	640.78	674.78	648.78	617.78	622.78	637.44
9/9/2010	925	1164	24.25	08/05/10	647.56 1 st egg laying by 3 rd gen females	668.56	702.56	676.56	645.56	650.56	665.22
9/16/2010	979	1297	27.6	09/15/10	964.22 Peak adult emerge 3 rd gen	985.22	1019.22	993.22	962.22	967.22	981.89
9/29/2010	1065	4154	88.38	10/06/10	1097.56 Peak egg laying by 3 rd gen females	1118.56	1152.56	1126.56	1095.56	1100.56	1115.22
10/6/2010	1100	7046	153.74	08/20/10	788.67 1 st adult emerge 4 th gen	809.67	843.67	817.67	786.67	791.67	806.33
10/13/2010	1130	11247	229.53	08/24/10	816.44 1 st egg laying by 4 th gen females	837.44	871.44	845.44	814.44	819.44	834.11
10/20/2010	1150	15795	329.06		1238.67 Peak adult emerge 4 th gen	1259.67	1293.67	1267.67	1236.67	1241.67	1256.33
10/27/2010	1162	16661	347.1								
11/3/2010	1180	52760	1146.96								
2011											
Year	DD 10C Jan	Fly Total	Avg% female	Best date est	Best cum. Dds C	Eugene KEUG	Aurora ARAO	Forest FOGO	GrMcMinnevil KMMV	Hillsboro KHIO	Average
6/21/2011	240	94	1.38	06/04/11	148.89 1 st egg laying by Ow females	156.89	172.89	157.89	136.89	124.89	149.72
6/28/2011	285	49	0.73	06/28/11	282.22 Peak (50%) egg laying by OW female	290.22	306.22	291.22	270.22	258.22	283.06
7/5/2011	338	51	0.75	06/29/11	290 1 st adult emerge 1 st gen	298	314	299	278	266	290.83
7/12/2011	388	115	1.88	07/18/11	423.33 Peak adult emerge 1 st gen	431.33	447.33	432.33	411.33	399.33	424.17
7/19/2011	435	177	2.64	07/03/11	317.78 1 st egg laying by 1 st gen females	325.78	341.78	326.78	305.78	293.78	318.61
7/26/2011	496	271	4.37	08/01/11	556.67 Peak egg laying by 1st gen females	564.67	580.67	565.67	544.67	532.67	557.5
8/3/2011	577	518	7.61	07/23/11	458.89 1 st adult emerge 2 nd gen	466.89	482.89	467.89	446.89	434.89	459.72
8/9/2011	630	1337	19.38	07/25/11	486.67 1 st egg laying by 2 nd gen females	494.67	510.67	495.67	474.67	462.67	487.5
8/16/2011	689	1930	27.97	08/17/11	697.78 Peak adult emerge 2 nd gen	705.78	721.78	706.78	685.78	673.78	698.61
8/23/2011	778	1869	28.75	08/29/11	831.11 Peak egg laying by 2 nd gen females	839.11	855.11	840.11	819.11	807.11	831.94
8/30/2011	843	2030	28.1	08/09/11	627.78 1 st adult emerge 3 rd gen	635.78	651.78	636.78	615.78	603.78	628.61
9/6/2011	907	3663	50.18	08/12/11	655.56 1 st egg laying by 3 rd gen females	663.56	679.56	664.56	643.56	631.56	656.39
9/13/2010	985	2842	39.47	09/12/11	972.22 Peak adult emerge 3 rd gen	980.22	996.22	981.22	960.22	948.22	973.06
9/20/2010	1035	7285	101.18	09/30/11	1105.56 Peak egg laying by 3 rd gen females	1113.56	1129.56	1114.56	1093.56	1081.56	1106.39
9/27/2011	1090	10708	150.82	08/26/11	796.67 1 st adult emerge 4 th gen	804.67	820.67	805.67	784.67	772.67	797.5
				08/28/11	824.44 1 st egg laying by 4 th gen females	832.44	848.44	833.44	812.44	800.44	825.28
				none	1246.67 Peak adult emerge 4 th gen	1254.67	1270.67	1255.67	1234.67	1222.67	1247.5

Model Version 2.0 – subset of all events	
DDs (50) F	
1	261 1st egg laying by OW females
2	501 Peak (50%) egg laying by OW females
3	515 1st adult emerge 1st gen
4	565 1st egg laying by 1st gen females
5	755 Peak adult emerge 1st gen
6	995 Peak egg laying by 1st gen females; max 2+ gens.
7	1248.8 Peak adult emerge 2nd gen; max 3+ gens.
8	1488.8 Peak egg laying by 2nd gen females; max 4+ gens.
9	1742.8 Peak adult emerge 3rd gen; max 5 gens.
10	1982.8 Peak egg laying by 3rd gen females; max 6+ gens.
11	2236.8 Peak adult emerge 4th gen; max 6+ gens.
12	2476.8 Peak egg laying by 4th gen females; max 7+ gens.
13	2730.8 Peak adult emerge 5th gen; max 8+ gens.
14	2970.8 Peak egg laying by 5th gen females; max 9+ gens.

total	DD F	DD C
# gens	261	145
ow gen		
1 gen	515	286.11
2 gen	819	455
3 gen	1123	623.89
4 gen	1427	792.78
5 gen	1731	961.67
6 gen	2035	1130.56
7 gen	2339	1299.44
8 gen	2643	1468.33
9 gen	2947	1637.22
10 gen	3251	1806.11

Corvallis 1971-2000

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

Normals	Average	Best cum.	Dds ©	Dds (F)
DDs (50) F	Date	Dds (10) C	Average	
261	05/18/00	144.9 1 st egg laying by OW females	154.1	277.45
501	06/14/00	278.2 Peak (50%) egg laying by OW females	287.5	517.45
515	06/15/00	286.0 1 st adult emerge 1 st gen	295.3	531.45
755	07/04/00	419.3 Peak adult emerge 1 st gen	428.6	771.45
565	06/19/00	313.8 1 st egg laying by 1 st gen females	323.0	581.45
995	07/19/00	552.7 Peak egg laying by 1st gen females; max 2+ gens.	561.9	1011.45
819	07/08/00	454.9 1 st adult emerge 2 nd gen	464.1	835.45
869	07/11/00	482.7 1 st egg laying by 2 nd gen females	491.9	885.45
1249	08/02/00	693.8 Peak adult emerge 2nd gen; max 3+ gens.	703.0	1265.45
1489	08/16/00	827.1 Peak egg laying by 2nd gen females; max 4+ gens.	836.4	1505.45
1123	07/26/00	623.8 1 st adult emerge 3 rd gen	633.0	1139.45
1173	07/29/00	651.6 1 st egg laying by 3 rd gen females	660.8	1189.45
1743	08/31/00	968.2 Peak adult emerge 3rd gen; max 5 gens.	977.5	1759.45
1983	09/17/00	1101.6 Peak egg laying by 3 rd gen females; max 6+ gens.	1110.8	1999.45
1427	08/12/00	792.7 1 st adult emerge 4 th gen	801.9	1443.45
1477	08/15/00	820.4 1 st egg laying by 4 th gen females	829.7	1493.45
2237	10/14/00	1242.7 Peak adult emerge 4th gen; max 6+ gens.	1251.9	2253.45
2477 none		1376 Peak egg laying by 4 th gen females; max 7+ gens.	1385.25	2493.45
2731 none		1517.11 Peak adult emerge 5th gen; max 8+ gens.	1526.36	2747.45
2971 none		1650.44 Peak egg laying by 5 th gen females; max 9+ gens.	1659.69	2987.45

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

Model of Oviposition Schedule based on Kanzawa – Table 10

Generation	1935		Cum Days (68.6 avg)	Dds	OV	Cum OV	Dds	Cum Percent	Hybrid Estimate	
	OV Period Days									
1	26		0		0	1	1	0	0.35	5.74
2	10		5.38		100	45	46	100	16.08	20.74
3	25		10.75		200	60	106	200	37.06	35.74
4	25		16.13		300	55	161	300	56.29	50.74
5	42		21.51		400	50	211	400	73.78	73.89
6	50		26.88		500	35	246	500	86.01	84.01
7	59		32.26		600	25	271	600	94.76	92.27
8	52		37.63		700	15	286	700	100	99.25
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:

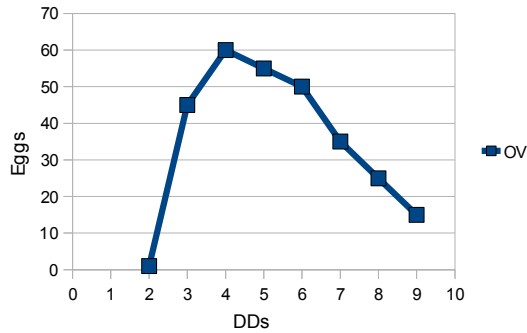
avg 38.9
 range 10 to 59 days

DDs (50)	Linear Model	Log Model	Hybrid Model
	Percent OV	Percent OV	Percent OV
0		5.74	5.74
50		13.24	13.24
100		20.74	20.74
150		28.24	28.24
200		35.74	35.74
250		43.24	43.24
300		50.74	50.74
350		58.24	58.24
400		65.74	73.89
450		73.24	79.23
500		80.74	84.01
550		88.24	88.33
600		95.74	92.27
650		103.24	95.9
700		110.74	99.25

using avg Temp = 68.6 F

Use 240 Dds
 As 50% ov
 switch pt->

Model of OV schedule



SWD Oviposition Model
 Kanzawa Data and Hybrid model Est.

