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Fruit Pest Events and Phenological Development According to Accumulated Heat Units

A. M. Agnello, D. P. Kain, and S. M. Spangler Department of Entomology, New York State Agricultural Experiment Station, Geneva

DEVELOPMENTAL RATES AND DEVELOPMENTAL THRESHOLDS

Mammals are "warm-blooded" and develop at a constant rate regardless of the environmental temperature, because they are able to maintain an internal temperature that allows their biochemical reactions to progress normally. Insects, which are "exothermic" (the same temperature as their environment; there is no such thing as "cold-blooded"), do not generate body heat, and are therefore limited in their development to periods of favorable external temperature. Below a certain temperature, which varies among species, the insect's biochemical reactions cannot proceed, and development stops. This temperature is known as the insect's **developmental threshold** ordevelopmental **base.** By charting the ambient temperature, it is possible to keep track of insect development, which is directly proportional to the amount of time accumulated above the developmental threshold (up to some maximum not often reached during the season). We arbitrarily divide this time into heat units, or **degree-days (DD).**

DEGREE-DAY CALCULATION METHODS

There are a few different ways to determine the quantity of heat units accumulated, which is equivalent to the area under a temperature vs. time graph on a given day. The methods vary in their ability to measure small changes during the day or departures from idealized heating and cooling trends (Fig. 1).

a. Average or Max/Min Method — This is the simplest and least precise method of calculating DD's. It assumes that the daily temperature graph is linear, and that the area under it is a triangle:

$$DD = \frac{[\text{Daily max temp} + \text{Daily min temp*}]}{2} - \text{Developmental Threshold}$$

(* - If Daily min temp < Developmental Threshold, substitute Developmental Threshold)

b. Sine Wave (Baskerville-Emin) Method — This is more precise, and assumes that the daily temperature cycle is approximated by the form of a sine wave. The area beneath this curve is determined by integration, which requires the knowledge of some calculus. This method makes the same use of daily maximum and minimum temperatures and developmental threshold, as does the Average Method. Using the Sine Wave Method tends to accumulate more DD's than the Average Method, particularly during the early part of the season.

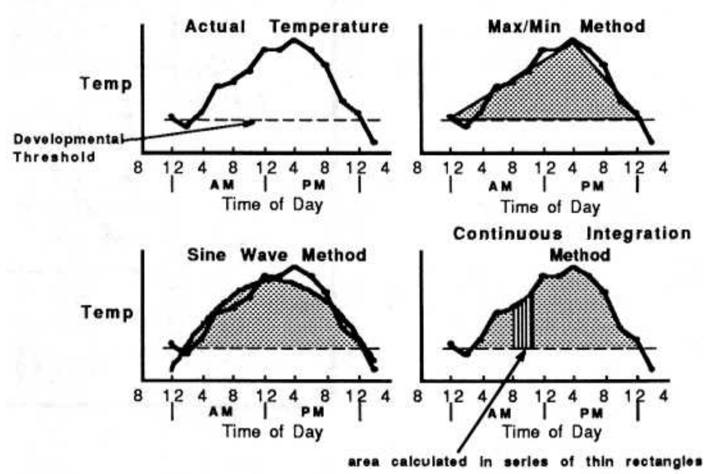


Figure 1. - Various methods used to calculate degree days.

c. Continuous Integration Method — This method is the most precise, and requires multiple temperature readings throughout the day, hourly or more frequently, to obtain a temperature vs. time graph that is truly representative of a field situation. The area beneath the curve is still calculated using integration. Consequently, the data collection is most efficient if handled by a computer.

RELATING DEGREE-DAYS TO LIFE CYCLE AND DEVELOPMENT

All the following methods are attempts to *correlate* some pest event or activity with something else that can be measured more precisely. Often, events in an insect's life cycle occur after the same heat units have accumulated each year, but many years' observations must be collected to measure this precisely. Degree-days can be used to predict the occurrence of these events anywhere weather data is available.

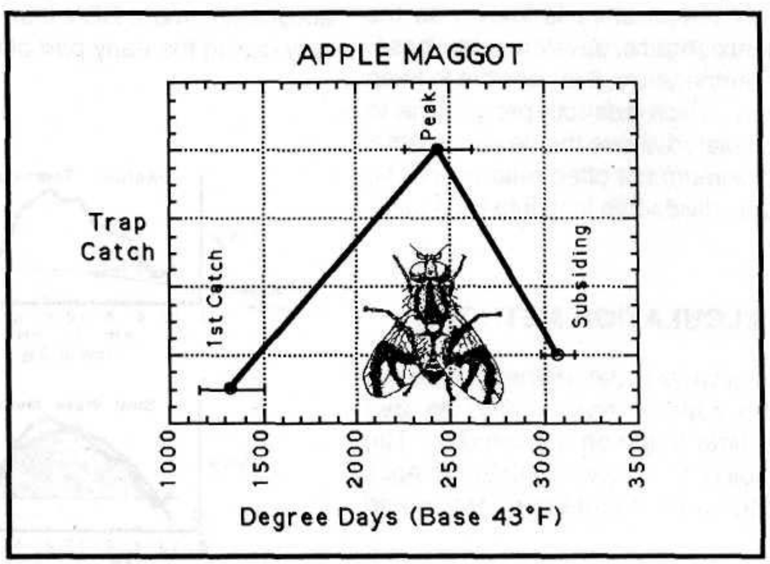
a. Temperature — By monitoring temperature and pest activity at the same time, and repeating the observations over many years, it is possible to build up a data base of events and the range of accumulated DD's corresponding with them.

b. Phenology — Some events reliably occur at the same time as other, easily observed biological events in the field; e.g., mites hatch at late tight cluster to pink; European apple sawfly egg-laying occurs at late bloom to petal fall. These rules of thumb often draw on the evolved relationships between pests and their hosts, and in some cases are more relevant than are DD's.

c. Biofix — This is a distinct, easily monitored event in the life history of an organism, used to "fine-tune" our predictions of their activity, e.g., first flight; first egg laid; first mine observed. Later life stages can be predicted more accurately after such an event is noted.

Following is a list of fruit development and pest events for which some DD information has been collected. This list can be used to help predict the occurrence of pest and phenological events in New York fruit plantings. Degree-day values, which were calculated using the Sine Wave Method, are provided for two common base temperatures associated with these events, 43°F and 50°F. The dates and DD units are given in ranges ± 1 standard deviation of the mean value observed; that is, events should occur within the stated range approximately seven years out of 10.

EVENT	Number of Observations	DATE From	DATE To	DD_{43} From	DD_{43} To	DD_{50} From	DD_{50} To
AM 1st catch	26	19-Jun	6-Jul	1161	1501	715	971
AM peak	7	24-Jul	24-Aug	2262	2620	1554	1740
AM subsiding	3	31-Aug	22-Sep	2986	3162	1966	2179
BCFF 1st catch	5	9-Jun	15-Jun	702	934	380	576
CFF 1st catch	10	8-Jun	24-Jun	755	1289	424	806



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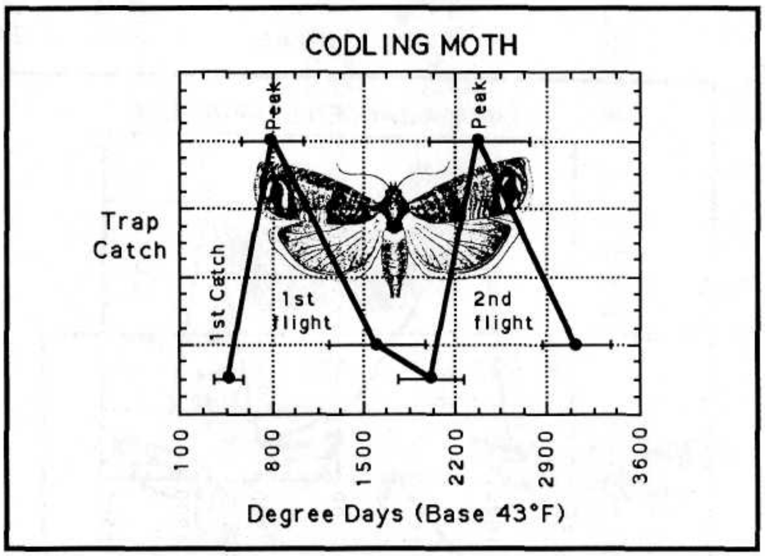
EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
CM 1st catch	20	11-May	27-May	364	589	176	326
CM 1st flight peak	10	21-May	18-Jun	561	1042	299	623
CM 1 st flight subsiding	5	29-Jun	27-Jul	1229	1978	761	1292
CM 2nd flight start	7	20-Jul	3-Aug	1770	2269	1148	1522
CM 2nd flight peak	9	25-Dec	3-Jun	2002	2775	1338	1893
CM 2nd flight subsiding	5	31-Aug	18-Sep	2863	3384	1916	2336



EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
CMB 1st gen. crawlers in pear buds	4	2-May	4-May	215	441	80	254
CMB 1st adult catch	4	27-Jun	7^Jul	1240	1677	730	1123
CMB 1st flight peak	4	2-Jul	18-Jul	1570	1743	978	1158
CMB 1st flight subsiding	3	13-Jul	13-Aug	1979	2231	1317	1445
CMB 2nd gen. crawlers emerging	5	20-Jul	19-Aug	2214	2501	1497	1649
CMB 2nd gen. crawlers increasing	4	17-Jul	21-Aug	2012	2638	1292	1811
CMB 2nd gen. crawlers peak	4	22-Jul	21-Aug	2380	2624	1658	1737
DWB 1st catch	3	5-Jun	27-Jun	791	1175	450	714
DWB peak catch	3	14-Jul	26-Jul	1584	2022	1005	1337
ERM overwintered egg hatch	12	1-May	14-May	221	341	96	162
ERM 1st summer eggs	3	21-May	25-May	456	572	235	321
ERM summer egg hatch	2	6-Jun	6-Jun	748	970	413	611
GAA present	4	11-APR	3-May	111	265	38	134
GFW 1st catch	11	26-Mar	14-Apr	45	107	8	47
GFW peak flight	6	10-Apr	26-Apr	92	214	31	100
GFW flight subsiding	7	30-Apr	19-May	252	424	102	222
LAW 1 st catch	5	28-Apr	26-May	192	523	82	254
LAW 1st flight peak	2	16-May	11-Jun	563	900	326	496
LAW 1st flight subsiding	2	2-Jun	3-Jul	1002	1390	644	834
LAW 2nd flight peak	2	6-Sep	23-Sep	2916	3221	1882	2191
LAW 2nd flight subsiding	2	8-Sep	17-Oct	3162	3297	2013	2245
LPTB 1st catch	22	18-May	4^Jun	427	756	208	426
LPTBpeak	6	19-Jun	28-Jul	1110	2088	682	1370
LPTB flight subsiding	4	2-Sep	14-Sep	2878	3309	1887	2305

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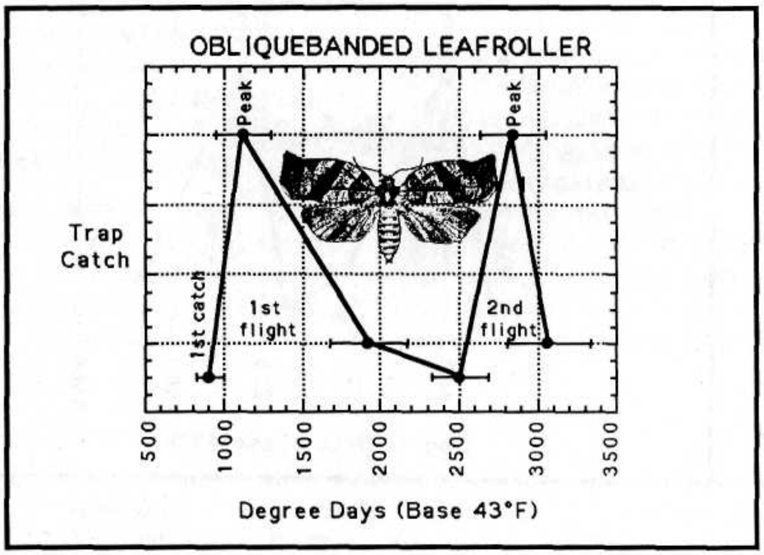
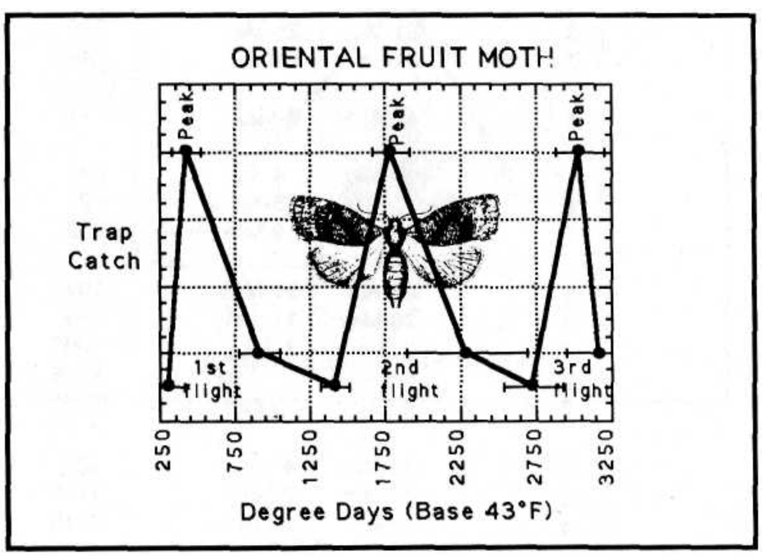
EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
OBLR larvae active	11	21-Apr	5-May	149	289	58	142
OBLR pupae present	3	30-May	7-Jun	573	841	308	496
OBLR 1st catch	33	6-Jun	15-Jun	823	999	469	605
OBLR 1st flight peak	17	10-Jun	29-Jun	942	1303	560	815
OBLR summer larvae hatch	4	20-Jun	6-Jul	1038	1460	625	957
OBLR 1st flight subsiding	20	11-Jul	4-Aug	1685	2176	1081	1447
OBLR 2nd flight start	14	29-Jul	19-Aug	2329	2693	1564	1851
OBLR 2nd flight peak	9	8-Aug	7-Sep	2638	3051	1797	2084
OBLR 2nd flight subsiding	6	14-Aug	23-Sep	2807	3333	1911	2271



OFM 1st catch	18	27-Apr	8-May	204	409	75	224
OFM 1st flight peak	9	3-May	26-May	326	522	160	274
OFM 1st flight subsiding	5	1-Jun	17-Jun	773	1051	430	646
OFM 2nd flight start	10	25^Jun	8-Jul	1321	1510	809	969
OFM 2nd flight peak	7	4-Jul	21-Jul	1661	1914	1067	1267
OFM 2nd flight subsiding	4	19-Jul	10-Aug	1895	2693	1241	1893
OFM 3rd flight start	3	10-Aug	26-Aug	2538	2932	1733	2013
OFM 3rd flight peak	5	23-Aug	15-Sep	2881	3207	1910	2220
OFM 3rd flight subsiding	5	24-Aug	2-Oct	2962	3381	2000	2288



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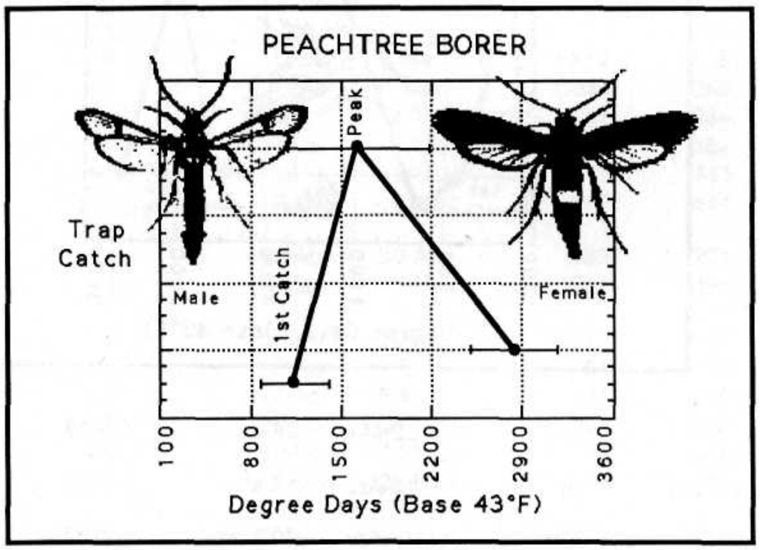
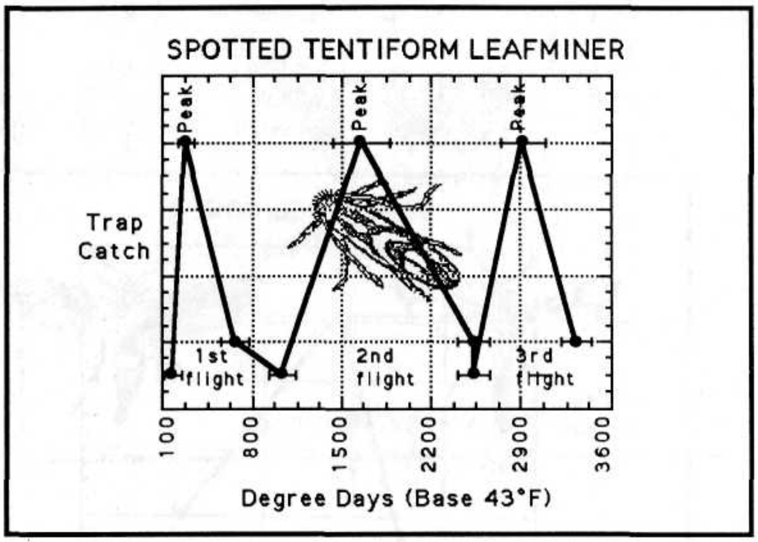
EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
PC in white trap	3	22-Apr	12-May	155	433	54	231
PC ovip scars present	10	15-May	3-Jun	475	638	246	322
PEAR THRIPS in pear buds	3	9-Apr	30-Apr	118	214	50	98
PPS.adults active	7	13-Mar	22-Apr	28	118	4	34
PPS 1st exposition	12	25-Mar	19-Apr	38	134	10	59
PPS 1st egg hatch	5	25-Apr	9-May	150	272	63	93
PPS nymphs present	3	1-May	7-May	197	324	72	178
PPS hard shell present	3	11-May	2-Jun	516	648	278	334
PPS 1st summer gen. adults	2	31-May	12-Jun	737	885	428	526
PPS 2nd brood hatch	3	7-Jun	15-Jun	967	1185	584	750
PREDATOR MITES observed	4	30-Apr	22-May	211	402	-93	210
PTB 1st catch	14	9-Jun	30-Jun	869	1400	511	876
PTB peak flight	7	16-Jun	31-Jul	1087	2186	674	1447
PTB flight subsiding	9	9-Aug	8-Sep	2503	3178	1680	2203



EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
RAA nymphs present	14	18-Apr	2-May	133	236	56	114
RBLR 1st catch	34	11-Apr	25-Apr	94	276	29	135
RBLR 1st flight peak	11	24-Apr	15-May	202	382	88	191
RBLR 1st flight subsiding	11	20-May	5-Jun	554	795	288	466
RBLR 2nd flight start	11	25Jun	8-Jul	1305	1590	803	1028
RBLR 2nd flight peak	5	5-Jul	19-Jul	1485	1835	907	1228
RBLR 2nd flight subsiding	8	23-Jul	19-Aug	2144	2535	1429	1703
RBLR 3rd flight peak	5	12-Aug	3-Sep	2656	3160	1825	2185
RBLR 3rd flight subsiding	2	16-Sep	8-Oct	3048	3499	1947	2398
SBW present	11	3-May	19-May	239	433	99	231
SJS 1st catch	29	8-May	24-May	359	597	177	322
SJS 1st flight peak	9	24-May	8-Jun	633	735	345	417
SJS 1st flight subsiding	6	5-Jun	16-Jun	831	1039	479	640
SJS Istgen crawlers present	7	11-Jun	27-Jun	1033	1215	619	757
SJS 2nd flight start	2	1-Jul	31-Jul	1384	1829	847	1161

EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
STLM 1st catch	40	12-Apr	25-Apr	105	244	35	119
STLM 1st opposition	5	22-Apr	2-May	146	224	60	104
STLM 1st flight peak	10	28-Apr	10-May	218	343	87	175
STLM sap-feeders	5	7-May	4^Jun	323	621	163	315
STLM mines forming	5	10-May	20-May	363	559	156	320
STLM 1st flight subsiding	10	20-May	6-Jun	552	780	283	447
STLM 2nd flight start	16	5-Jun	20-Jun	929	1140	545	700
STLM 2nd flight peak	11	2-Jul	20-Jul	1433	1871	898	1230
STLM 2nd gen. tissue feeders	3	24-Jun	17-Jul	1378	2035	913	1182
STLM 2nd flight subsiding	8	15-Jul	6-Aug	2402	2663	1231	1595
STLM 3rd flight start	8	2-Aug	19-Aug	2402	2663	1591	1857
STLM 3rd flight peak	8	20-Aug	6-Sep	2737	3086	1832	2149
STLM 3rd flight subsiding	4	3-Sep	14-Sep	3208	3452	2180	2451



EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
SRW present	3	22-May	26-Jul	519	2147	289	1435
SYRPHID predator eggs present	3	10-Apr	14-May	135	307	61	135
TPB adults present/active	20	10-Apr	10-May	117	327	43	167
TPB present in strawberry	3	18-May	6-Jun	551	709	297	400
TPB nymphs incr. in blackberry	3	7-Jun	9-Jun	774	870	447	491
TPB adults 1st incr. in blackberry	3	15-Jun	17-Jun	1759	1847	1146	1222
TPB adults 2nd incr. in blackberry	3	17-Jul	27-Jul	1877	2099	1239	1413
WALH nymphs on apple	9	7-May	18-May	268	559	130	303
WALH 2nd brood nymphs	3	28-Jun	3-Sep	1601	2856	1026	1921
APPLEPH silver tip	8	29-Mar	15-Apr	57	106	12	44
MACPH silver tip	2	31-Mar	23-Apr	63	68	17	19
APPLEPH green tip	9	10-Apr	24-Apr	59	131	18	54
MACPH green tip	9	4-Apr	16-Apr	49	153	17	63
APPLEPH half-inch green	7	22-Apr	28-Apr	128	196	49	100
MACPH half-inch green	9	12-Apr	29-Apr	142	207	62	94
APPLEPH tight cluster	9	22-Apr	7-May	184	269	75	133
MACPH tight cluster	6	21-Apr	4-May	205	255	83	122
APPLEPH pink	8	29-Apr	14-May	239	370	96	173
MACPH pink	4	25-Apr	11-May	264	297	116	148
APPLEPH bloom	14	1-May	20-May	296	450	142	234
MACPH bloom	10	2-May	17-May	336	417	163	216
APPLEPH petal fall	9	15-May	28-May	396	557	200	307

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EVENT	Number of Observations	DATE From	DATE To	DD43 From	DD43 To	DD50 From	DD50 To
MACPH petal fall	5	11-May	21-May	427	514	217	277
MACPH fruit set	3	13-May	27-May	477	681	258	346
APRICOTPH bloom	5	9-Apr	28-Apr	189	231	75	111
PEACHPH swollen bud	4	1O-Apr	20-Apr	76	174	25	81
PEACHPH half-inch green	3	16-Apr	4-May	157	198	59	100
PEACHPH pink	11	18-Apr	7-May	185	243	76	113
PEACHPH bloom	10	29-Apr	10-May	242	366	105	161
PEACHPH petal fall	8	1-May	23-May	280	555	150	276
PEARPH swollen bud	7	8-Apr	20-Apr	93	175	27	77
PEARPH bud burst	9	16-Apr	1-May	106	224	46	101
PEARPH green cluster	6	26-Apr	8-May	211	266	83	124
PEARPH white bud	7	27-Apr	13-May	233	363	101 181	
PEARPH white bud	7	27-Apr	13-May	233	363	101	181
PEARPH bloom	10	29-Apr	15-May	275	385	128	197
PEARPH petal fall	9	5-May	23-May	362	452	173	234
PEARPH fruit set	4	10-May	30-May	442	552	234	288
PLUMPH swollen bud	3	7-Apr	26-Apr	124	180	53	82
PLUMPH bud burst	6	25-Apr	3-May	119	235	50	99
PLUMPH green cluster	6	26-Apr	8-May	211	265	83	124
PLUMPH white bud	2	1-May	12-May	225	264	91	117
PLUMPH bloom	6	2-May	13-May	266	382	115	207
PLUMPH petal fall	6	8-May	19-May	317	443	137	237
PLUMPH shuck split	3	18-May	30-May	342	544	150	290
STRBPHnobuds	2	30-Apr	30-Apr	159	201	71	81
STRBPH buds show to bloom	3	7-May	27-May	367	495	132	256
SWCHERRYPH bud swell	4	4-Apr	19-Apr	77	135	24	65
SWCHERRYPH bud burst	5	16-Apr	1-May	151	222	63	102
SWCHERRYPH white bud	7	24-Apr	8-May	181	250	81	108
SWCHERRYPH bloom	10	29-Apr	12-May	223	303	95	142
SWCHERRYPH petal fall	5	6-May	17-May	303	445	152	237
SWCHERRYPH fruit set	4	11-May	22-May	399	496	199	270
TARTCHERRYPH swollen bud	3	9-Apr	24-Apr	65	219	19	104
TARTCHERRYPH bud burst	8	19-Apr	4-May	170	262	72	124
TARTCHERRYPH white bud	3	11-May	15-May	248	321	104	136
TARTCHERRYPH bloom	5	6-May	14-May	283	423	141	231
TARTCHERRYPH petal fall	4	12-May	20-May	398	506	200	277

Key to abbreviated names:

Pest Names

AM = Apple maggot
BCFF = Black cherry fruit fly
CFF = Cherry fruit fly
CM = Codling moth
CMB = Comstock mealybug
DWB = Dogwood borer
ERM = European red mite
GAA = Green apple aphid
GFW = Green fruitworm
LAW = Lesser appleworm
LPTB = Lesser peachtree borer
MAC = Mclntosh
OBLR = Obliquebanded leafroller
OFM = Oriental fruit moth
PC = Plum curculio
PPS = Pear psylla
PTB = Peachtree borer
RAA = Rosy apple aphid
RBLR = Redbanded leafroller
SBW = Strawberry bud weevil(clipper)
SJS = San Jose scale
SRW = Strawberry root weevil
STLM = Spotted tentiform leafminer
STRB = Strawberry
TPB = Tarnished plant bug
WALH = White apple leafhopper
...PH = (crop) phenology