Using Degree-Days and Plant Phenology to Predict Pest Activity

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Accurate prediction of insect development and emergence is essential for effective pest management, but can be quite challenging. The great diversity of ornamental plants, each with its own complement of insect pests, creates a logistical challenge for planning and implementing a successful pest management program for landscapes and nurseries. Pesticide applications must be timed precisely to maximize effectiveness and minimize the number required. Improperly timed applications are expensive and even make problems worse when they decrease populations of natural enemies without impacting the target pest. Many insects are difficult to detect and monitor, further complicating the accurate timing of pesticide applications. Consequently, pesticide applications are frequently scheduled on a calendar-day basis. However, because of tremendous variation in the weather from location to location and year to year, calendar-based scheduling is frequently inaccurate.

Insects emerge earlier in warm years than in cool ones. Since insect development is temperature dependent, monitoring degree-day accumulation is a valuable tool for predicting pest activity. Although degree-days are simple to calculate, monitoring degree-days on a daily basis can be cumbersome. Plants also bloom earlier during warm than cool years. Since plant development is also temperature dependent, monitoring plant phenology, such as flowering time, can be used to track degree-day accumulation and predict insect activity. If a sequence of plant phenological events can be shown to correspond with the appearance of insect pests, then the easily monitored phenological sequence could be used as a biological calendar to anticipate the order and time pests reach vulnerable stages. This chapter describes when degree-days and plant phenology can be used effectively to predict insect emergence and time pest management activities.

What Are Degree-Days?

A degree-day (also referred to as a growing degree-day, heat unit, or thermal unit) is a measure of the amount of heat that accumulates above a specified base temperature during a 24-hour period. One degree-day accumulates for each degree the average temperature remains above a specified base-temperature over those 24 hours, and several degree-days can accumulate during a 24-hour period. However, it is important to understand that degree-days have meaning only in relation to the base temperature that has been specified.

Insect development occurs only between an upper and lower temperature threshold. Development stops when the temperature drops below the lower threshold and resumes when it rises above it. Ideally, when attempting to predict plant and insect development, the lower temperature threshold for development is used as the base temperature for calculating degree-days. The lower developmental threshold temperature is known only for only a few insect pests, but experience has shown that 50·F is a reasonable approximation for many species, and it is commonly used as the base temperature (although other temperatures such as 32·F and 42·F are also sometimes used).

Development of plants and insects also stops when the temperatures exceed the upper threshold for development. In midwestern and northern climates, the upper temperature threshold is not generally exceeded for long enough periods to be an important consideration, and is often ignored when calculating degree-days. Furthermore, many key pests of ornamental plants are active in the spring and early summer before extremely hot weather is a factor in their development. In southern climates, it may be important to factor the upper temperature threshold into degree-day calculations for some pests.

Calculating Degree-Days

There are a number of ways to calculate degree-days, ranging from quite simple to those so complex that a computer is required. The three methods are the Average Method, the Modified Average Method, and the Modified Sine Wave Method. All three methods calculate degree-days from the daily minimum and maximum temperature, and a specified base temperature. During a typical 24-hour day, the minimum temperature is usually reached just before dawn and the maximum temperature during mid-afternoon. Daily temperature data can be obtained from a thermometer that records maximum and minimum temperatures, or from a nearby weather station. Figure 1 depicts the temperature pattern for a hypothetical day in which the maximum and minimum temperatures were 45·F and 65·F, respectively. In this example, 50·F is used as the base temperature.

Figure 1.

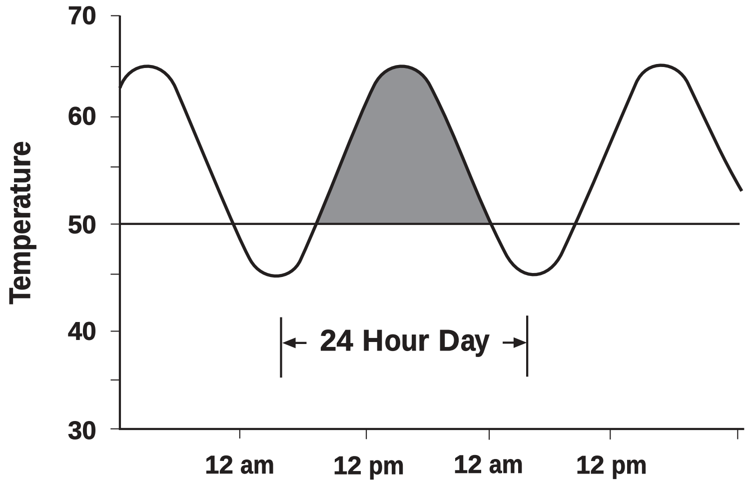

Figure 1. Change in temperature over the course of a typical day follows a predictable pattern with the minimum temperature generally occurring just before dawn and the maximum temperature in mid-afternoon. In this hypothetical day, the maximum temperature was 65·F, the minimum temperature was 45·F, and the base temperature has been specified as 50·F (which approximates the lower developmental threshold for many plants and insects). The shaded area under the temperature curve and above the base temperature represents degree-day accumulation during this hypothetical day.

The Average Method

The Average Method is the easiest method for calculating the number of degree-days. Simply add the daily maximum and minimum temperatures and divide the sum by two to get the average temperature for the day. Then subtract the base temperature from the average temperature:

Degree-days = [(max temp + min temp) / 2] – base temp

Using this method, 5 degree-days accumulated during the day depicted in Figure 1:

[(65 + 45) / 2] – 50 = 5 degree-days

If the maximum temperature for the day never rises above the base temperature, then no development occurs, and zero degree-days accumulate (we don’t calculate negative degree-day values since the development of organisms does not reverse when it is cold).

The Modified Average Method

When the daily temperature fluctuates above and below the base temperature (as it does frequently in the spring), the Average Method can underestimate the number of degree-days actually experienced by a plant or insect. This is because development occurs even during the short periods that the temperature is above the base temperature, no matter how cold it may be during the rest of the day. In this situation, the Modified Average Method will calculate a higher number of degree-days, and thus can be more accurate for predicting pest activity than the Average Method.

The Modified Average Method is calculated in the same way as the Average Method, except that the base temperature is substituted for the minimum temperature when the minimum temperature drops below the base temperature (as it does in the example shown in Figure 1) according to the following formula:

Degree days = [(max temp + base temp) / 2] – base temp

Using this method, 7.5 degree-days accumulated during the day depicted in Figure 1, as opposed to 5 degree-days as calculated using the Average Method:

[(65 + 50) / 2] – 50 = 7.5 degree-days

The Modified Sine Wave Method

The Modified Sine Wave Method is even more accurate when the minimum temperature drops below the base temperature. This method makes use of the fact that daily temperature patterns closely resemble a sine wave function, and determines the amount of degree-days by calculating the amount of area under the temperature curve and above the base temperature (shaded portion of Figure 1). On days when the minimum temperature remains above the base temperature, this method yields the same result as the Average Method. Most people find the Modified Sine Wave Method too complex to calculate without a computer. Table 1 can be used as a reference to determine the number of degree-days that accumulate on days when the minimum temperature falls below the base temperature.

Table 1. Daily degree-day accumulation calculated using the Modified Sine Wave Method when the minimum daily temperature falls below a base temperature of 50·F.

Maximum Temperature	Minimum Temperature						
	20	25	30	35	40	45	50
50	0	0	0	0	0	0	0
55	0	1	1	1	1	1	1
60	2	2	2	2	2	3	4
65	3	3	4	4	4	5	6
70	5	5	5	6	6	7	9
75	7	7	7	8	9	10	11
80	9	9	10	10	11	12	14
85	11	11	12	13	13	15	16
90	13	13	14	15	16	17	19
95	15	16	16	17	18	19	21

Using Degree-Days to Predict Insect and Plant Development

Degree-days can be valuable tools for predicting insect development and timing pest management practices. Table 2 outlines the steps to follow. The easiest way to construct a degree-day model is to monitor a phenological event from one year to the next (for example, adult emergence of bronze birch borer, or flowering of crabapple), and by noting the total number of degree-days that have accumulated since a particular starting date. Cumulative degree-days are the total number of degree-days that have accumulated since a designated starting-date, and they are calculated simply by adding the number of degree-days that accumulate each day. Any date can be used as the starting-date, but January 1 is used most commonly because many overwintering plants and insects do not resume development until they are first exposed to a period of cold.

Table 2. Steps to follow in the construction of a degree-day model.

1. **Identify and monitor a phenological event of a plant and/or pest (e.g., first bloom, egg hatch).**
2. **Determine an appropriate base temperature. If the lower developmental threshold is not known for the species being monitored, use 50·F.**
3. **Select a starting date for degree-day accumulation (January 1 in most cases).**
4. **Record daily maximum and minimum temperatures for your locale (or obtain them from the nearest weather station).**
5. **From the maximum and minimum temperature, calculate the number of degree-days that accumulate each day.**
   - **5a. If the minimum temperature does not fall below the base temperature, use the Average Method.**
   - **5b. If the minimum temperature does fall below the base temperature, use the Modified Sine Wave method (degree-day values using this method can be obtained from Table 1).**
6. **When the phenological event that is being monitored occurs, note the total number of degree-days that have accumulated since the starting date.**
7. **Use this value to predict the occurrence of the phenological event in future years.**

In practice, the number of degree-days required for a particular phenological event can vary from one year to the next. For example, in Wooster, Ohio emergence of bronze birch borer adults first occurred at 475 degree-days in 1997, 519 degree-days in 1998, 654 degree-days in 1999, 559 degree-days in 2000, and 526 degree-days in 2001, for a 5-year average of 547. There are several potential reasons for this. If the lower threshold temperature varies substantially from the selected base temperature (in this case 50·F), then large differences could occur from year to year in the number degree-days calculated for a particular event such as insect emergence.

Furthermore, January 1 may not be the best starting date to begin totaling degree-days. For some insect species, the overwintering stage can undergo significant development prior to winter in the late summer and fall. In this case, a starting-date from the previous summer or fall will be more accurate. For example, one study found that adult emergence of bronze birch borer was most accurately predicted in Columbus, Ohio using a starting date of May 1 and a base temperature of 46·F. Evaluating different starting dates and base temperatures over several years can help determine the most accurate combination for calculating cumulative degree-days. There are a number of even more sophisticated methods for modeling insect phenology. However, because of the limitations described below, these models are often no more accurate when applied in the field than the simpler methods described above.

Limitations of Degree-Day Models

The greatest source of error in degree-day models lies in the temperature data used to calculate degree-days. It is virtually impossible to measure the temperature that the pests actually experience. Microenvironments in which insects exist are generally very different from the environment of the thermometer used to collect the temperature data. Furthermore, many insects exert some control over their body temperatures through their behavior. For example, they will move to dark surfaces in the sun when they are too cool, and to light surfaces in the shade when they are too warm.

Researchers can develop highly accurate models by recording temperatures directly in the insect's environment (for example, by affixing a microprobe directly to the insect). However, these temperatures will differ enough from those measured by nearby weather stations that the value of such models will be limited when used with data obtained from local weather stations. For this reason, practical models are often developed from temperature data collected from the same standardized sources that users have access to, such as local weather stations. Experience has shown that over several years, errors in estimating insect development using standardized data tend to cancel themselves out, leading to models that are accurate for practical purposes.

There are other sources of error in degree-day models, but they tend to be relatively small. For example, the methods used to calculate degree-days assume that the development rate of insects is a linear function of temperature. However, temperature has nonlinear effects on insect and plant development, which begins to slow dramatically as the temperature approaches the upper and lower threshold. When the temperature oscillates around the base temperature for long periods of time, as it tends to do in early spring, errors in prediction can become fairly substantial. Degree-day models also assume that development rate is only a function of temperature. However, other factors have important effects on development time. For example the nutritional quality of the plants that insects feed on can be impacted by fertilization regimes, which can affect insect growth rates. Similarly, drought can affect the developmental rate of plants and soil-borne insects. Yet because the effects of these factors on insect development are difficult to quantify and relatively insignificant compared with temperature, they are generally not considered in degree-day models.

Despite such limitations, degree-day models have great practical value for predicting insect and plant development in the field. Even simple models that use the Average Method to calculate cumulative degree-days from a base temperature of 50·F and a starting date of January 1 have proven to be much more accurate than calendar-based schedules for timing most pest management practices.

Using Plant Phenology to Predict Insect Activity

Although degree-days are simple to calculate, monitoring degree-days on a daily basis can be cumbersome. An alternative approach is to let plants do the work for you by using plant phenological events as indicators of pest activity. Phenology is the study of recurring biological phenomena and their relationship to weather. Bird migration, blooming of wildflowers and trees, and the seasonal appearance of insects are examples of phenological events that have been recorded for centuries. Since plant development is also temperature dependent, plants respond to degree-day accumulation in the same way that insects do. This means that plant phenological events, such as flowering time, can be used to track degree-day accumulation and predict insect activity. Furthermore, a sequence of phenological events, such as the blooming times of ornamental plants, can be used as a biological calendar to anticipate the order and time when various insect pests reach vulnerable stages. This can greatly simplify the logistics of planning and scheduling monitoring programs, pesticide applications, and other pest management activities for the large number of pests that infest ornamental plants.

The critical assumption in the use of plant phenology to predict pest activity is that the phenological sequence (the order in which phenological events occur) remains constant from year to year even when weather patterns differ greatly. This hypothesis was evaluated in 5-year studies conducted in central Michigan and northeastern Ohio. The phenology of a large number of plants and pests at the Dow Gardens in Midland, Michigan from 1985-1989, and at the Secrest Arboretum at The Ohio State University's Ohio Agricultural Research and Development Center in Wooster from 1997-2001 were monitored. The weather during both 5-year studies varied dramatically. For example, in Ohio the spring of 1997 was very cool, while 1998 (the year of *El Niño*) was quite warm, and the springs of 1999-2001 were closer to "normal."

Plants were monitored at least three times each week, and the dates of "first bloom" and "full bloom" recorded. "First bloom" is defined as the date on which the first flower bud on the plant opens revealing pistils and/or stamens, and "full bloom" as the date on which 95% of the flower buds have opened (i.e., one bud out of twenty has yet to open). These phenological events can be identified and recorded with precision. In contrast to methods used to monitor plant phenology, which were designed to minimize variation in order to increase predictive power, sampling methods used for insects and mites were designed to characterize the phenology of the entire population. For each event, both the date of occurrence and the number of cumulative degree-days (using a starting date of January 1 and a base temperature of 50·F) were recorded.

The phenological sequences for Michigan and Ohio are presented in Tables 3 and 4, respectively. The average date of occurrence is presented only to provide a frame of reference; it is the sequence in which the events occur that is most significant. The dramatic variation in weather resulted in differences of up to four weeks in the dates on which these events occurred from year to year. However, the order in which the phenological events occurred remained quite consistent from year to year. For example, in both Michigan and Ohio, egg hatch of pine needle scale always occurred just as common lilac reached full bloom, and emergence of bronze birch borer adults always began just as black locust was blooming (even though there was substantial variation in the calendar date from year to year).

Phenological sequences can be used very effectively as **biological calendars** for scheduling pest management activities. For example, when common lilac is blooming, a glance at the calendar would reveal that it was still too early to monitor for bronze birch borer emergence. Conversely, once black locust has bloomed, the calendar would show that it was too late to control the first generation of pine needle scale.

The great consistency in phenological patterns from year to year demonstrates that even one year of observations is useful for timing pest management decisions. This means that pest managers can readily create, expand, and customize their own biological calendars. Once the basic sequence has been established, any additional plants or pests can be added later. When a pest is observed or a pesticide application is made, a pest manager can note what plants happen to be in bloom at that time. If follow-up monitoring showed the application to be effective, then the timing can be accurately duplicated the following season by monitoring the same plants. If the application was found to be too early or too late, then the timing of the application in future years could be delayed or accelerated relative to the phenological sequence.

A critical question is whether a phenological sequence from one region will be valid in other regions. The Michigan and Ohio studies can be compared directly because there is substantial overlap between them in the species monitored, and because both studies used identical methodology. A statistical analysis revealed a very high degree of correspondence between them ($r = 0.98$). The vast majority of phenological events occurred in the same order in both locations. However, there were a few deviations.

Gypsy moth egg hatch occurred a little earlier in the Michigan sequence, where it hatched as Bradford callery pear was blooming (Table 3). In Ohio, however, gypsy moth egg hatch did not begin until crabapples and redbuds began blooming, which occurs after Bradford callery pear has passed full bloom (Table 4). There were a small number of even more dramatic deviations. For example, egg hatch of the banded form of oystershell scale occurred much earlier in the Michigan sequence (just as Vanhoutte spirea began blooming) than in the Ohio sequence (two weeks after first bloom of Vanhoutte spirea), even when both were monitored on the same host plant, common lilac. Imported willow leaf beetle adults also emerged much earlier in Michigan than in Ohio.

The high degree of correspondence between Michigan and Ohio suggests that a phenological sequence developed in one region can generally be used effectively elsewhere. The few significant deviations between them, however, suggests that users may want to confirm the accuracy of these phenological sequences in their own regions to be on the safe side. But again, this requires only one year of observation.

In summary, calculating degree-days can be an effective tool for predicting insect emergence. Biological calendars consisting of the flowering sequence of ornamental trees and shrubs can also be used quite accurately to track degree-day accumulation and predict pest activity. The use of such indicators for timing pest activity holds tremendous potential for improving the effectiveness of IPM programs in nurseries and landscapes.

Table 3. Phenological sequence including average date of occurrence and cumulative degree-days for the Dow Gardens in Midland, Michigan from 1985–1989. Insects are indicated in bold type. Degree-days were calculated using a base temperature of 50·F and a starting date of January 1.

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Silver Maple	first bloom	24-Mar	11
Silver Maple	full bloom	4-Apr	30
Cornelianchery Dogwood	first bloom	7-Apr	46
Eastern Tent Caterpillar	**egg hatch**	**8-Apr**	**47**
Red Maple	first bloom	9-Apr	49
Red Maple	full bloom	13-Apr	67
Border Forsythia	first bloom	15-Apr	71
Cornelianchery Dogwood	full bloom	16-Apr	75
Star Magnolia	first bloom	17-Apr	83
Korean Rhododendron	first bloom	18-Apr	85
Manchu Cherry	first bloom	22-Apr	93
Border Forsythia	full bloom	22-Apr	97
Norway Maple	first bloom	22-Apr	103
White Pine Weevil	**adult emergence**	**25-Apr**	**110**
Pine Engraver	**adult emergence**	**25-Apr**	**112**
Korean Rhododendron	full bloom	25-Apr	114
Star Magnolia	full bloom	25-Apr	114
Imported Willow Leaf Beetle	**adult emergence**	**27-Apr**	**116**
Weeping Higan Cherry	first bloom	27-Apr	119
PJM Rhododendron	first bloom	26-Apr	131
Manchu Cherry	full bloom	27-Apr	131
Bradford Callery Pear	first bloom	27-Apr	132
Gypsy Moth	**egg hatch**	**28-Apr**	**148**
Apple Serviceberry	first bloom	29-Apr	153
Norway Maple	full bloom	29-Apr	154
Weeping Higan Cherry	full bloom	1-May	155
Common Floweringquince	first bloom	29-Apr	155
PJM Rhododendron	full bloom	3-May	172
Apple Serviceberry	full bloom	3-May	176
Eastern Redbud	first bloom	3-May	177
Bradford Callery Pear	full bloom	4-May	182
Hawthorn Leafminer	**adult emergence**	**4-May**	**183**
Japanese Flowering Cherry	first bloom	4-May	184
Alder Leafminer	**adult emergence**	**5-May**	**189**
Koreanspice Viburnum	first bloom	5-May	189
Birch Leafminer	**adult emergence**	**5-May**	**189**
Japanese Flowering Crab	first bloom	6-May	200
Snowdrift Crabapple	first bloom	6-May	205
Common Lilac	first bloom	7-May	207
Common Floweringquince	full bloom	7-May	208
Sargent Crabapple	first bloom	7-May	213
Wayfaringtree Viburnum	first bloom	9-May	227

Table 3. (continued)

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Japanese Flowering Cherry	full bloom	9-May	227
Elm Leafminer	**adult emergence**	**9-May**	**228**
Koreanspice Viburnum	full bloom	10-May	233
Coral Burst Crabapple	first bloom	10-May	239
Ohio Buckeye	first bloom	10-May	241
Eastern Redbud	full bloom	11-May	254
Snowdrift Crabapple	full bloom	11-May	255
Tatarian Honeysuckle	first bloom	12-May	259
Common Horsechestnut	first bloom	12-May	260
Japanese Flowering Crab	full bloom	12-May	267
Pine Needle Scale	**egg hatch - 1st generation**	**13-May**	**277**
Sargent Crabapple	full bloom	14-May	282
Cooley Spruce Gall Adelgid	**egg hatch**	**13-May**	**283**
Eastern Spruce Gall Adelgid	**egg hatch**	**13-May**	**283**
Wayfaringtree Viburnum	full bloom	14-May	287
Coral Burst Crabapple	full bloom	14-May	296
Blackhaw Viburnum	first bloom	15-May	301
Doublefile Viburnum	first bloom	15-May	301
Black Cherry	first bloom	15-May	308
Redosier Dogwood	first bloom	16-May	311
Slender Deutzsia	first bloom	16-May	320
Common Lilac	full bloom	17-May	323
Lilac Borer	**adult emergence**	**16-May**	**324**
Vanhoutte Spirea	first bloom	17-May	329
Ohio Buckeye	full bloom	18-May	342
Common Horsechestnut	full bloom	18-May	344
Lesser Peach Tree Borer	**adult emergence**	**20-May**	**362**
Oystershell Scale	**egg hatch**	**19-May**	**363**
Blackhaw Viburnum	full bloom	20-May	370
Pagoda Dogwood	first bloom	20-May	376
Doublefile Viburnum	full bloom	21-May	398
Black Cherry	full bloom	22-May	405
Tatarian Honeysuckle	full bloom	22-May	406
Redosier Dogwood	full bloom	22-May	408
Winter King Hawthorn	first bloom	24-May	411
Beautybush	first bloom	26-May	429
Vanhoutte Spirea	full bloom	25-May	429
Black Locust	first bloom	27-May	455
White Fringetree	first bloom	29-May	480
Winter King Hawthorn	full bloom	29-May	485
Pagoda Dogwood	full bloom	29-May	488
Common Ninebark	first bloom	30-May	507
White Fringetree	full bloom	31-May	528
Bronze Birch Borer	**adult emergence**	**2-Jun**	**550**
Black Locust	full bloom	3-Jun	564
Beautybush	full bloom	3-Jun	565
Greater Peach Tree Borer	**adult emergence**	**3-Jun**	**573**
Euonymus Scale	**egg hatch - 1st generation**	**3-Jun**	**575**
Golden Oak Scale	**egg hatch**	**6-Jun**	**625**
Common Ninebark	full bloom	7-Jun	636
Mountain-laurel	first bloom	8-Jun	654
Juniper Scale	**egg hatch**	**11-Jun**	**697**
Washington Hawthorn	first bloom	12-Jun	708

Table 3. (continued)

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Japanese Tree Lilac	first bloom	12-Jun	710
Rosebay Rhododendron	first bloom	15-Jun	757
Northern Catalpa	first bloom	15-Jun	759
Mountain-laurel	full bloom	17-Jun	803
Greenspire Littleleaf Linden	first bloom	19-Jun	828
Washington Hawthorn	full bloom	18-Jun	830
Japanese Tree Lilac	full bloom	20-Jun	860
American Elder	first bloom	21-Jun	870
Fletcher Scale	**egg hatch**	**20-Jun**	**884**
Cottony Maple Scale	**egg hatch**	**23-Jun**	**930**
Northern Catalpa	full bloom	24-Jun	937
Greenspire Littleleaf Linden	full bloom	26-Jun	985
American Elder	full bloom	28-Jun	1019
Black Pineleaf Scale	**egg hatch**	**29-Jun**	**1068**
European Fruit Lecanium Scale	**egg hatch**	**29-Jun**	**1073**
Panicled Goldenraintree	first bloom	3-Jul	1137
Spruce Budscale	**egg hatch**	**4-Jul**	**1154**
Panicled Goldenraintree	full bloom	13-Jul	1361

Table 4. Phenological sequence including average date of occurrence and cumulative degree-days for Secrest Arboretum in Wooster, Ohio from 1997-2001. Insect and spider mites are indicated in bold type. Degree-days were calculated using a base temperature of 50·F and a starting date of January 1.

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Silver Maple	first bloom	2-Mar	34
Corneliancherry Dogwood	first bloom	16-Mar	40
Silver Maple	full bloom	19-Mar	42
Red Maple	first bloom	24-Mar	44
Japanese Pieris	first bloom	27-Mar	60
Red Maple	full bloom	28-Mar	75
Star Magnolia	first bloom	31-Mar	83
Border Forsythia	first bloom	30-Mar	86
Eastern Tent Caterpillar	**egg hatch**	**1-Apr**	**92**
Manchu Cherry	first bloom	29-Mar	93
Corneliancherry Dogwood	full bloom	1-Apr	98
Norway Maple	first bloom	3-Apr	116
Border Forsythia	full bloom	4-Apr	116
Sargent Cherry	first bloom	4-Apr	127
Larch Casebearer	**egg hatch**	**6-Apr**	**128**
Japanese Pieris	full bloom	7-Apr	129
Saucer Magnolia	first bloom	5-Apr	133
Common Floweringquince	first bloom	8-Apr	137
Bradford Callery Pear	first bloom	9-Apr	142
European Pine Sawfly	**egg hatch**	**10-Apr**	**144**
Weeping Higan Cherry	first bloom	10-Apr	145
PJM Rhododendron	first bloom	11-Apr	147
Norway Maple	full bloom	11-Apr	149
Inkberry Leafminer	**adult emergence**	**11-Apr**	**150**
Sargent Cherry	full bloom	10-Apr	151
Star Magnolia	full bloom	11-Apr	151

Table 4. (continued)

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Allegheny Serviceberry	first bloom	16-Apr	153
Manchu Cherry	full bloom	8-Apr	155
Apple Serviceberry	first bloom	17-Apr	159
Spruce Spider Mite	**egg hatch**	**13-Apr**	**162**
Bradford Callery Pear	full bloom	15-Apr	164
Allegheny Serviceberry	full bloom	19-Apr	169
Saucer Magnolia	full bloom	18-Apr	174
PJM Rhododendron	full bloom	19-Apr	178
Boxwood Psyllid	**egg hatch**	**17-Apr**	**179**
Weeping Higan Cherry	full bloom	20-Apr	179
Apple Serviceberry	full bloom	21-Apr	182
Koreanspice Viburnum	first bloom	21-Apr	185
Japanese Flowering Crab	first bloom	22-Apr	189
Eastern Redbud	first bloom	23-Apr	191
Gypsy Moth	**egg hatch**	**23-Apr**	**192**
Snowdrift Crabapple	first bloom	23-Apr	198
Koreanspice Viburnum	full bloom	24-Apr	205
Azalea Lace Bug	**egg hatch**	**23-Apr**	**206**
Common Floweringquince	full bloom	27-Apr	214
Birch Leafminer	**adult emergence**	**26-Apr**	**215**
Coral Burst Crabapple	first bloom	27-Apr	217
Elm Leafminer	**adult emergence**	**24-Apr**	**219**
Alder Leafminer	**adult emergence**	**25-Apr**	**224**
Honeylocust Spider Mite	**egg hatch**	**27-Apr**	**227**
Wayfaringtree Viburnum	first bloom	29-Apr	229
Sargent Crabapple	first bloom	29-Apr	230
Honeylocust Plant Bug	**egg hatch**	**30-Apr**	**230**
Tatarian Honeysuckle	first bloom	30-Apr	233
Common Lilac	first bloom	1-May	234
Persian Lilac	first bloom	1-May	240
Ohio Buckeye	first bloom	2-May	245
Eastern Redbud	full bloom	2-May	245
Snowdrift Crabapple	full bloom	2-May	250
Common Horsechestnut	first bloom	4-May	251
Hawthorn Lace Bug	**adult emergence**	**29-Apr**	**253**
Japanese Flowering Crab	full bloom	3-May	254
Hawthorn Leafminer	**adult emergence**	**1-May**	**260**
Coral Burst Crabapple	full bloom	5-May	263
Flowering Dogwood	first bloom	5-May	263
Red Buckeye	first bloom	5-May	265
Blackhaw Viburnum	first bloom	6-May	269
Imported Willow Leaf Beetle	**adult emergence**	**5-May**	**274**
Red Chokeberry	first bloom	6-May	281
Wayfaringtree Viburnum	full bloom	7-May	290
Sargent Crabapple	full bloom	7-May	298
Persian Lilac	full bloom	8-May	303
Red Horsechestnut	first bloom	7-May	304
Pine Needle Scale	**egg hatch - 1st generation**	**8-May**	**305**
Cooley Spruce Gall Adelgid	**egg hatch**	**8-May**	**308**
Eastern Spruce Gall Adelgid	**egg hatch**	**8-May**	**308**
Vanhoutte Spirea	first bloom	9-May	309

Table 4. (continued)

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Common Lilac	full bloom	9-May	315
Pink Princess Weigela	first bloom	8-May	316
Blackhaw Viburnum	full bloom	9-May	322
Redosier Dogwood	first bloom	10-May	323
Winter King Hawthorn	first bloom	10-May	328
Lilac Borer	**adult emergence**	**11-May**	**330**
Slender Deutzsia	first bloom	11-May	338
Common Horsechestnut	full bloom	12-May	344
Red Chokeberry	full bloom	12-May	351
Doublefile Viburnum	first bloom	12-May	353
Pagoda Dogwood	first bloom	13-May	363
Red Java Weigela	first bloom	13-May	365
Black Cherry	first bloom	13-May	368
Lesser Peach Tree Borer	**adult emergence**	**14-May**	**372**
Ohio Buckeye	full bloom	14-May	374
Holly Leafminer	**adult emergence**	**13-May**	**375**
Euonymus Scale	**egg hatch - 1st generation**	**16-May**	**406**
Vanhoutte Spirea	full bloom	16-May	406
Catawba Rhododendron	first bloom	17-May	407
Winter King Hawthorn	full bloom	17-May	407
Tatarian Honeysuckle	full bloom	17-May	410
Beautybush	first bloom	17-May	417
Black Cherry	full bloom	18-May	419
Miss Kim Manchurian Lilac	first bloom	18-May	422
White Fringetree	first bloom	19-May	435
Red Horsechestnut	full bloom	20-May	440
Doublefile Viburnum	full bloom	20-May	444
Pink Princess Weigela	full bloom	19-May	446
Redosier Dogwood	full bloom	20-May	448
Scarlet Firethorn	first bloom	21-May	459
Black Locust	first bloom	21-May	467
Red Buckeye	full bloom	21-May	471
Common Ninebark	first bloom	22-May	478
Pagoda Dogwood	full bloom	23-May	479
Sweet Mockorange	first bloom	22-May	482
Oystershell Scale	**egg hatch**	**24-May**	**497**
Miss Kim Manchurian Lilac	full bloom	24-May	498
Catawba Rhododendron	full bloom	25-May	503
White Fringetree	full bloom	25-May	517
Arrowwood Viburnum	first bloom	27-May	534
American Yellowwood	first bloom	27-May	546
Bronze Birch Borer	**adult emergence**	**28-May**	**547**
Black Locust	full bloom	27-May	548
Multiflora Rose	first bloom	28-May	548
Red Java Weigela	full bloom	29-May	565
Mountain-laurel	first bloom	30-May	565
Scarlet Firethorn	full bloom	30-May	565
Potato Leafhopper	**adult arrival**	**29-May**	**568**
Juniper Scale	**egg hatch**	**29-May**	**571**
Beautybush	full bloom	31-May	592
Chinese Dogwood	first bloom	1-Jun	593

Table 4. (continued)

Plant or Pest Name	Phenological Event	Average Date	Cumulative Degree-Days
Common Ninebark	full bloom	1-Jun	596
American Yellowwood	full bloom	28-May	599
Black Vine Weevil	**adult emergence**	**30-May**	**607**
Arrowwood Viburnum	full bloom	3-Jun	621
Japanese Tree Lilac	first bloom	2-Jun	622
Bumald Spirea	first bloom	3-Jun	624
Washington Hawthorn	first bloom	3-Jun	635
Multiflora Rose	full bloom	4-Jun	643
Northern Catalpa	first bloom	6-Jun	675
Greater Peach Tree Borer	**adult emergence**	**5-Jun**	**702**
American Elder	first bloom	6-Jun	707
Sweet Mockorange	full bloom	6-Jun	717
Washington Hawthorn	full bloom	7-Jun	731
Calico Scale	**egg hatch**	**8-Jun**	**748**
European Fruit Lecanium Scale	**egg hatch**	**9-Jun**	**767**
Striped Pine Scale	**egg hatch**	**10-Jun**	**783**
Japanese Tree Lilac	full bloom	13-Jun	808
Rhododendron Borer	**adult emergence**	**13-Jun**	**815**
Northern Catalpa	full bloom	13-Jun	816
Mountain-laurel	full bloom	14-Jun	822
Dogwood Borer	**adult emergence**	**14-Jun**	**830**
Oakleaf Hydrangea	first bloom	14-Jun	835
Cottony Maple Scale	**egg hatch**	**15-Jun**	**851**
Fall Webworm	**egg hatch**	**16-Jun**	**867**
Mimosa Webworm	**egg hatch - 1st generation**	**16-Jun**	**874**
Winged Euonymus Scale	**egg hatch**	**17-Jun**	**892**
Spruce Budscale	**egg hatch**	**17-Jun**	**894**
Greenspire Littleleaf Linden	first bloom	18-Jun	899
American Elder	full bloom	18-Jun	909
Bumald Spirea	full bloom	18-Jun	917
Panicled Goldenraintree	first bloom	19-Jun	924
Azalea Bark Scale	**egg hatch**	**18-Jun**	**957**
Japanese Beetle	**adult emergence**	**21-Jun**	**970**
Rosebay Rhododendron	first bloom	24-Jun	1010
Greenspire Littleleaf Linden	full bloom	24-Jun	1047
Bottlebrush Buckeye	first bloom	27-Jun	1158
Panicled Goldenraintree	full bloom	5-Jul	1251
Rose-of-Sharon	first bloom	8-Jul	1347
Pine Needle Scale	**egg hatch - 2nd generation**	**6-Jul**	**1349**
Euonymus Scale	**egg hatch - 2nd generation**	**26-Jul**	**1923**
Magnolia Scale	**egg hatch**	**4-Aug**	**1938**
Banded Ash Clearwing Borer	**adult emergence**	**14-Aug**	**2195**