Phenology

UNIVERSITY OF WISCONSIN–MADISON • DIVISION OF EXTENSION
FOUNDATIONS IN HORTICULTURE

In a nutshell...

- Phenology is a time-tested way of tracking natural events and using them to anticipate garden milestones.
- In Wisconsin there is no such thing as a "normal" weather year. There are usually extremes during at least one season out of every year.
- Check the resources at **hort.extension.wisc.edu** for issues not covered in this chapter.

MASTER GARDENER
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Introduction

Have you heard the expression "Plant corn when oak leaves are the size of a squirrel's ear"? Phenology is a branch of science that studies the relationships between periodic biological events—usually the life cycles of plants and animals—and seasonal temperatures. By noting when weed seeds germinate, insects emerge, or other events happen in relation to annual climatic variations, this information can be used to predict or correlate to other unrelated biological events.

This chapter explores the ways phenology can help you use integrated pest management procedures to target specific pest life stages predictably.

Learning objectives

1. Describe the concept of phenology in relation to integrated pest management.
2. Define an indicator plant.
3. Give an example of timing a control tactic for a specific insect or weed pest relative to a common flowering plant's bloom time.
4. Understand how degree days are calculated and how they can be used to predict the appearance of certain insect pests.

The history of phenology

The word phenology is derived from the Greek word *phaino*, meaning "to show" or "to appear." Natural events such as bird migration, ice thaw on local lakes, plant budding, flowering or fruiting, insect activities, and harvest dates of cultivated plants are all annual events that can be correlated with seasonal or climatic changes, particularly with weather or temperature, rather than specific calendar dates.

You may be familiar with folklore that associates gardening events with unrelated processes. One example is planting corn when oak leaves are the size of a squirrel's ear. You know that planting corn has nothing to do with oak leaves or squirrels. However, Native Americans made the observation centuries ago that the soil was warm enough to prevent seeds from rotting, yet it was still early enough to reap a suitable harvest if corn was planted at this time. This is an early example of phenology, but its origins can be traced back much further.

The first paper on phenology was written in 974 B.C.—long before meteorology, botany, and ornithology were born. The Japanese began recording the first bloom of the cherry trees in 812 A.D., and in Sweden Carl Linnaeus was one of the first European scientists to record observations of natural phenomena in the 1700s.

Closer to home, Aldo Leopold was one of the early phenologists in Wisconsin. He kept extensive records for his landmark publication of natural seasonal events near his home in Sauk County from 1935 to 1945. He, and later his family members and others, have kept the same records ever since.

How phenology works

When observing phenological events on a large scale, the same event—such as lilacs blooming—progresses from west to east and south to north. This phenomenon is referred to as Hopkin's Rule, which states that phenological events are delayed by four days per degree of north latitude and 1¼ days per degree of east longitude. Basically, the farther north or east you go, the later you'll see similar events. Hopkin's rule however, doesn't take into account altitude or topography—the latter being important in a state bordered on the east by Lake Michigan, which exerts a tremendous impact on the local climate.

By observing the relationship between distinct phenological events and the season, local weather conditions, or climate changes over a period of years, you can correlate seemingly unrelated events. Do this yourself in your own garden. Just keep careful records of dates when different plants bloom, when their leaves open, and when you first notice various insects. (Make sure the plants you're observing aren't affected by radiant heat from buildings or paved areas that could skew your data.) After several years of consistently collecting information in your garden diary you will be able to notice patterns and correlations with other events, such as when a particular insect starts causing damage. When you review your notes, it should become obvious that these annual events do not occur on the same date every year, but the timing differs depending on the weather.

Phenological correlations

Phenological records need to be gathered over many years in order to develop reliable correlations. This information can be used to help determine planting dates or predict when insect emergence will take place and pest management should be initiated. Many such correlations are based on the blooming time of common flowering plants. For example:

- Prune roses, plant peas, and apply crabgrass-preventing herbicides to lawns when forsythia blooms.
- Plant perennials when lilac flowers are in bud.
- Plant beans, cucumber and squash seeds when lilac flowers are fully opened.
- Plant tomatoes and frost-sensitive annual plants when lily-of-the-valley plants bloom.
- Check pine trees for sawfly larvae when Vanhoutte spirea is in full bloom.
- Set out eggplants, melons, peppers, and sweet potato vines when tall, bearded irises bloom.

Phenology and integrated pest management

Phenology can be very useful as part of an integrated pest management (IPM) program because it helps to properly target the most susceptible life stage of the pest. Insects are particularly well suited to predictions based on phenology because, as cold-blooded animals, their growth and development is directly correlated with weather conditions, particularly temperature.

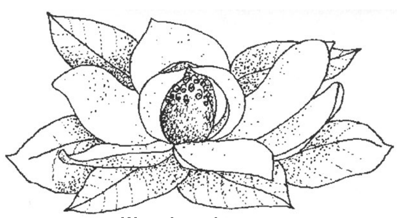
Indicator plants, common plants that may or may not be associated with the pest insect whose life stage they predict, can be used to determine when pest outbreaks are likely to occur. In general, good indicator plants are:

- Common to a wide geographical area.
- Perennially hardy.
- Easy to recognize.
- Easy to grow.

Indicator plants also tend to have short, well-defined bloom periods and blooms or fruits that are recognizable from a distance.

Examples of indicator plants include:

- The saucer magnolia is a common indicator plant for early spring events. Pink bud, early bloom, full bloom, past bloom, and petal drop are some of the discrete events of the saucer magnolia that can be associated with an array of landscape insect pests, such as Eastern tent caterpillar (early bloom), ash plant bug (full to late bloom), and European pine sawfly and gypsy moth larvae (dropping petals).



- The common lilac has become a cornerstone for phenological observations, particularly for comparing one year to the next. First leaf, first flower, and full bloom are three life events frequently observed with the common lilac. The common lilac was used in an observation program in the eastern United States and Canada that developed into the National Phenology Network. Climatologists use this information to study climate change.

- Bridal wreath spirea is another common indicator plant. When this plant is in full bloom, typically around Memorial Day in southern Wisconsin, oystershell scale crawlers have hatched and control should be initiated.
- Chicory is a summer-blooming indicator plant. When the first flowers of chicory open, the time is right to prevent damage from the squash vine borer and to start being vigilant for Japanese beetles.
- And when Canada thistle is in bloom, apple maggot adults are abundant and susceptible fruit should be protected.

Consider planting a "phenology garden" or incorporating some indicator plants into your landscape.

Degree days

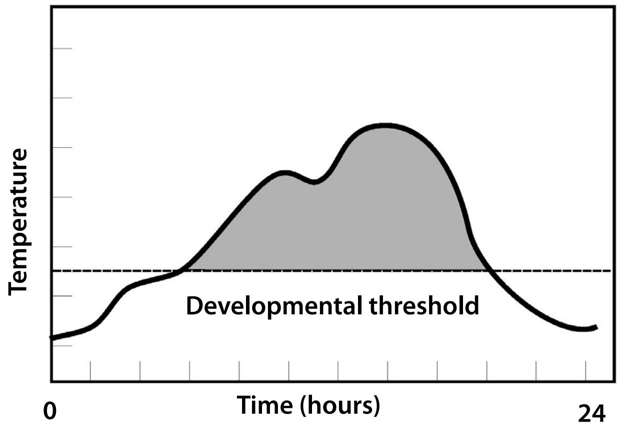
Indicator plants are not the only way to predict phenological events. Another way of achieving the same result of proper timing is to use degree day calculations. **Degree days** (also known as heat units or thermal units) are a way of incorporating both temperature and time into one measurement to quantify the rate of plant or insect development.

All plants and insects develop in response to temperature. The warmer the weather, the more quickly they develop, and the cooler the temperature, the slower they develop. But all of these species have a cutoff temperature below—and above—which no measurable development occurs. This base temperature, or developmental threshold, differs depending on the species and is determined by research. As the temperature increases above the threshold, plant and insect development occurs. The higher the temperature, the faster the rate of development.

The most common developmental threshold is 50˚F. This is the temperature at which dormancy is broken in plants and when many insects become active. But there are a number of insects, particularly those that are active early in the spring, that have a lower threshold (38˚ or 43˚F). Since most plants begin development at 50 to 52˚F, degree days for landscape plantings are calculated using a base temperature of 50˚F. Base temperatures are often noted as a subscript number following the abbreviation for degree day: DD_{50}.

Degree days are accumulated whenever the temperature exceeds the predetermined developmental threshold (i.e., 50˚F). A certain number of units are added every 24-hour period depending on how much the temperature is above threshold to produce a cumulative total of degree days. The mathematics for calculating actual degree days can be very complex (determining the area under the curve for the graph of time vs. temperature; see figure 1), but easy arithmetic equations yield approximations satisfactory for practical applications.

FIGURE 1. The gray area above the developmental threshold line shows the calculation of temperature over time. Each day gives actual degree days.



The basic procedure for calculating degree days is very simple; all you need is a maximum/minimum thermometer. Each day, record the high and low temperatures. Determine the average daily temperature by adding the daily high temperature and low temperature together and dividing by 2:

Average daily temperature = (high temp. + low temp.) ÷ 2

TABLE 1. Sample degree day accumulation

Date	Max	Min	ADT	DD_{50}	Total
1/1	18	6	12	0	0
1/2	15	-3	6	0	0
*					
*					
*					
4/1	45	36	40	0	0
4/2	52	39	45	0	0
4/3	65	45	55	5	5
4/4	62	48	55	5	10
4/5	71	47	59	9	19
4/6	53	39	46	0	19
4/7	56	50	53	3	22

Example:

Average daily temperature = (60 + 50) ÷ 2 = 55

Next, subtract the base temperature from the average daily temperature to get the number of degree days for that day:

Daily DD_{50} = avg. daily temp. – base temp.

Example:

Daily DD_{50} = 55 – 50 = 5 DD_{50}

If the difference between the average and the base temperatures is less than zero, just record zero, not a negative number.

Finally, to keep track of degree day accumulation, keep a running total of all degree days accumulated from the first of the year (table 1).

In Wisconsin, we often don't accumulate many degree days before April 1, so if you wish to take a break from the math from January to April, go ahead.

The above equation is a rough estimate of heat unit accumulation. There is also an upper threshold for development in insects, above which there is no appreciable increase in the rate of development. This is obviously of more concern later in the season than in the spring. To compensate for reduced growth rate at high temperatures, **modified degree days** use an upper threshold of 86˚F as well as the lower threshold. Whenever the actual temperature is below the base temperature, the base temperature is substituted as the low temperature for the day. Similarly, whenever the daily high is above 86˚, 86 is used as the high temperature for the day.

Example: Daily high = 90 and daily low = 45

Average daily temperature = (86 + 50) ÷ 2 = 68

Daily DD_{50} = 68 – 50 = 18 DD_{50}

However, if you're not inclined to dig out your calculator and record daily temperatures, the Wisconsin Department of Agriculture, Trade and Consumer Protection calculates average day degrees for different regions and publishes the information weekly during the growing season in their Wisconsin Pest Bulletin. Be aware that these numbers are averages calculated over a large area and may not be reflective of actual conditions in warmer or cooler microhabitats.

Degree day accumulations are not useful in and of themselves; you need to know what these numbers mean relative to the life cycle of specific pests you want to control. Over the years researchers have determined when (in terms of degree days) certain events occur in pest insect life cycles. By comparing our accumulated degree days against these data, we can determine when to take action in our own backyard.

For example, cabbage maggot flies first emerge at 300 DD_{43} (note that this is different from the more common base temperature of 50 degrees). Almost as soon as the flies emerge, they start laying eggs. We want to prevent the adults from laying eggs on the plant since cabbage maggot larvae are nearly impossible to control after they've attacked the plant roots. When we reach 300 DD_{43} (or probably a little before), it's time to do something to protect the plants—whether that's to cover the plants so the flies can't get to the plants, delay planting cabbages until after the flies have died, or spray an insecticide to kill the flies. You also need to be aware that this will happen again later in the season: be prepared for the emergence of second and third generation flies at 1476 and 2652 DD_{43} and take protective measures at those times, too.

Table 2 lists some common insect pests and when specific life cycle events critical to the control of these pests occur.

Conclusion

Phenology incorporates the first two tiers of an integrated pest management (IPM) strategy: knowledge of the pest and the use of decision-making aids to help select a pest management tactic. You need to have a basic understanding of the pest life cycle if you are watching for correlated biological events. Learning to use degree days is another tool that can help inform decisions about the timing of management. Consider adding phenology to your IPM strategy to help make the best pest management choices for both human health and the environment.

TABLE 2. Degree days for specific life events for some common landscape plant, fruit, and vegetable crop pests

Pest	Base temperature	Degree days	Event
Apple maggot	50	1100	first eggs laid
Birch leafminer	50	275–50	1st generation larva
Cabbage maggot	43	300	1st generation adults
Codling moth	50	550	1st gen.; peak egg laying
Colorado potato beetle	52	185	first eggs laid
Common asparagus beetle	50	150	first eggs laid
Cottony maple scale	50	850	crawlers first appear
Eastern tent caterpillar	50	100	1st instar larvae
Emerald ash borer	50	275–500	1st instar larvae
Gypsy moth	50	200–350	larvae begin hatching
Imported cabbageworm	50	150–240	first adult butterflies appear
		300–400	first larvae
Japanese beetle	50	900–1200	adults appear
Oystershell scale	50	275–500	crawlers first appear
Squash vine borer	50	1000	egg laying begins

Resources

Wisconsin Horticulture publications are available at hort.extension.wisc.edu.

FAQs

What phenological markers are most commonly tracked?

The dates of the first and last frosts, when the ground freezes and thaws, the best time to hunt morel mushrooms, the blooming of herbaceous and woody landscape plants, and the emergence of insect pests.

What else can people do with an understanding of phenology?

If you're serious about phenology, you can become a phenological observer. The Wisconsin Phenological Society and USA National Phenology Network offer advice to help you with observations and to contribute to larger collections of data.

Phenology, practice exam questions

1. **Phenology is:**
   a. The correlation of natural events with seasonal or climatic changes, especially temperature
   b. Calculated using Hopkin's Rule
   c. A method of integrated pest management
   d. All of the above
2. **A practical use of phenology is:**
   a. apply crabgrass-preventing herbicides to lawns when lilacs bloom
   b. Apply crabgrass-preventing herbicides to lawns when forsythia blooms
   c. Plant tomatoes when lilacs bloom
   d. Plant tomatoes when irises bloom
3. **Indicator plants in general:**
   a. Are perennials
   b. Are easy to grow
   c. Have short, well-defined bloom periods
   d. All of the above
4. **The saucer magnolia is a common indicator plant with flower stages associated with landscape insect pests including:**
   a. Eastern tent caterpillar (early bloom)
   b. European pine shoot moth (full bloom)
   c. Gypsy moth adults (dropping petals)
   d. All of the above
5. **Degree days calculations are based on:**
   a. The fact that plants and insects develop in response to temperature
   b. A developmental threshold that varies by species
   c. Incorporating both temperature and time to quantify the rate of development
   d. All of the above
6. **The most common developmental threshold is:**
   a. 0˚F
   b. 32˚F
   c. 50˚F
   d. 86˚F
7. **The basic procedure for calculating degree days is:**
   a. Add the minimum and maximum temperatures for the day
   b. Calculate the average daily temperature and add the base temperature
   c. Calculate the average daily temperature and subtract the base temperature
   d. Subtract the base temperature from the maximum temperature for the day
8. **Degree day accumulations are useful for:**
   a. Predicting when Colorado potato beetle, asparagus beetle and squash vine borer will start laying eggs
   b. Determining when cottony maple scale crawlers should be treated
   c. Estimating when larvae of eastern tent caterpillars will hatch
   d. All of the above

Answer key
1. (a.) 2. (b) 3. (d) 4. (a) 5. (d) 6. (c) 7. (c) 8. (d)