Insect Degree-Day Models for Turf: An Important Integrated Pest Management Tool

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The principles of integrated pest management (IPM) are easy to agree with. We know that it is in everyone's best interest to prevent insect populations from reaching damaging levels, rather than having to treat an outbreak. It is intuitive that the insect's most susceptible life stage should be the target of control measures. And it makes sense that biological and cultural control methods should be the first line of defense against insects, with more toxic insecticides used only as a last resort.

In practice, however, these principles can be difficult to implement because it is difficult to detect insects when they are present at low levels, it is not always possible to tell what life stage of the insect is present, and biological and cultural controls can be ineffective if this type of information is unavailable.

A tool that predicts when each life stage of an insect will appear could improve the ability of golf course superintendents to implement IPM. The good news is that such a tool exists; over the last 15 years, degree-day models which use temperature to forecast insect population development have been generated for several turf insect pests. The bad news is that these models have rarely left the laboratory for use on-site at golf courses.

In this **Insights**, the development and use degree-day models will be reviewed, and the reasons for their lack of use on golf courses will be explored. Finally, actions that will help result in increased use of degree-day models will be recommended.

The historical development of the degree-day concept

<u>The effect of temperature on plant and animal growth:</u> The value of using temperature to predict plant and animal growth was recognized by the French scientist Renè A. F. de Rèaumur in 1735. By adding together the daily average air temperatures that occurred during the life cycle of several different plant species, he discovered that the sum of temperatures for each species was the same from year to year, even though the number of days required for development varied. In other words, a **thermal constant**, or a specific amount of heat was required for a plant to reach maturity, and this amount of heat was characteristic for each plant species or variety.

<u>The need for degree-day units:</u> The concept of the thermal constant, which applies to insects, plants and other ectothermic or "cold-blooded" organisms, is the basis for development of the degree-day concept. At the turn of the 20th century, scientists began to propose that the thermal constant be expressed in units which came to be called **degree days**.

Since the first degree-day models were proposed early this century, over one hundred models now exist that forecast everything from the harvest dates of grains, vegetables and fruits to optimal crop planting dates to the best crop varieties for different geographical areas. Beginning in the 1970s, many degree-day models were developed for insect pests ranging from the alfalfa weevil to the vegetable leafminer.

Degree-day theory and calculations

<u>Developmental Thresholds</u>: All organisms live within a relatively narrow range of temperatures above and below which their survival becomes difficult. The **lower developmental threshold** is the temperature at or below which growth stops. The **upper developmental threshold** is the temperature at or above which growth slows down or stops. The number of degree-days accumulated in one day is the total amount of heat between the lower and upper thresholds.

<u>Degree-day calculations</u>**:** In the simplest terms, degree-days are units of total accumulated heat. Generally, each developmental stage of an organism has a characteristic degree-day requirement. For example, from the time an insect egg is laid until the time larvae hatch from the egg may require 100 degree-days, while the time period between larval hatch and pupation may require 175 degree-days.

The way in which temperature data is utilized determines the complexity of the degree-day model. The simplest degree-day models rely on recording only the daily minimum and maximum temperatures. These temperatures are added together and divided by two to determine the average daily temperature, as illustrated in Example 1 below.

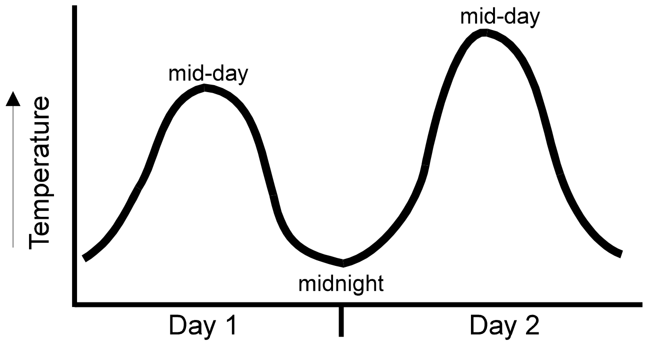
Example 1: Using minimum and maximum temperatures to determine daily average temperatures.

1. The minimum temperature recorded for the day is 55° F and the maximum temperature for the same day is 75° F. The average temperature for the day is then (75° F + 55° F)/2 = 65° F.
2. The black turfgrass ataenius (BTA) has a lower development threshold of 55° F. Therefore, the total number of degree-days accumulated by BTA for this day is (65° F - 55° F) X 1 day = 10 degree-days.

The type of calculation described above has the advantage that degree-days can be determined using only a thermometer that records maximum and minimum temperatures and a simple hand calculator. However, this method has been criticized by many for ignoring the fact that temperatures fluctuate significantly during the day. To remedy this, several models now rely on weather data that is averaged on an hourly, rather than on a daily basis.

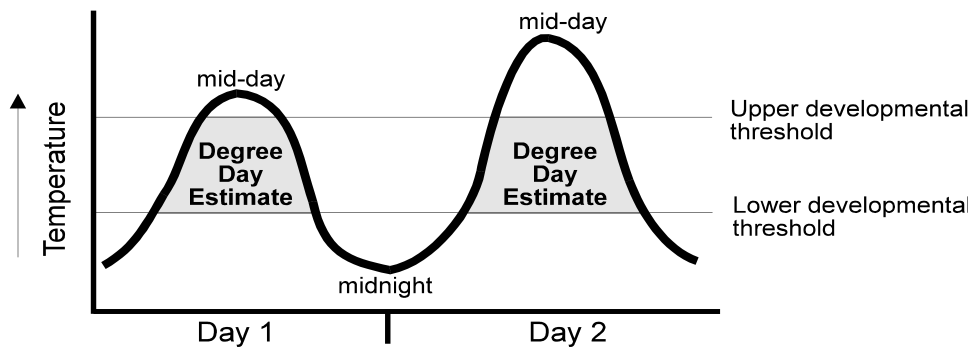
Additional precision in temperature data can be achieved by using the maximum and minimum temperatures to generate a **sine curve**, an operation that is easily performed on a personal computer. Because the sine curve does a good job of simulating a 24 hour temperature cycle with cooler temperatures in the early morning and late evening and the highest temperatures during mid-day (Figure 1), it becomes possible to take a more detailed look at daily temperature cycles, and thus to achieve even more precision in degree-day estimates.

Figure 1. Temperature cycle for two 24 hour periods, as illustrated by a sine curve.



Using the **sine curve method**, a computer model estimates degree-days by calculating the area above the lower threshold temperature and below the upper threshold temperature. The shaded areas in Figure 2 represent the number of degree-days accumulated for each of the two days.

Figure 2: Calculation of degree-days using the sine curve method. The area indicated by shading equals the number of degree-days for each 24 hour period. Through the use of published computer programs, the shaded areas under the sine curve can be easily calculated and converted into degree-day values.



Degree-day models for turf insect pests

Degree-day models have been published for several insect pests of turf including BTA, sod webworm, annual bluegrass weevil, bluegrass billbug, hairy chinch bug, Northern and Southern masked chafers and frit flies. A description of two of the most damaging of these pests and the role degree-day models play in their control is presented below.

<u>Black turfgrass ataenius</u>: Until recently only a problem in the Eastern U.S., this beetle has become a serious pest of cool season turf in Arizona and California in the past ten years. The damaging stage is the larvae, or grubs, which cause damage by feeding on plant roots. Because the adults are small (1/5” long) and cause no damage to turf and the larvae live in the thatch layer where they are difficult to detect, an ataenius infestation may go unnoticed until heavy grub infestations have caused extensive damage to turf.

The fact that these pests are hard to see with the naked eye has led to the use of methods that allow superintendents to “see” the pests in other ways. For example, black light trapping of adults has been used to determine when insects will appear. However, traps must be checked on a regular basis, and the insects must be counted and correctly identified, all time consuming tasks.

As a less labor intensive and more flexible alternative, a degree-day model was developed by Wegner and Niemczyk at the Ohio Agricultural Research and Development Center. Using a minimum developmental threshold temperature of 55.4°F, the model predicts the timing of egg laying for each of two generations. The use of this model allows more accurate timing of control treatments made against larvae and adults. As a result, it should be possible to achieve more effective control and to reduce the number of sprays needed to keep the black turfgrass ataenius below damaging levels.

Sod webworms: Also known as lawn moths, there are several species of sod webworm that are pests on both cool-season and warm season turfgrass throughout the U.S. The small adult moths do not feed on turf, but the larval or caterpillar stage causes two types of damage. Direct damage results from larval feeding on blades and crowns of grass plants. Indirect damage results from birds searching for webworm larvae.

Sod webworms are one of the few turf insects for which an effective biological control is commercially available. The bacterium, *Bacillus thuringiensis* var. *kurstaki* is active against the larval stage, particularly newly hatched larvae, but detecting the presence of these small insects is difficult. The use of a soap solution drench that is irritating to the larvae has been used successfully to bring black cutworm and other caterpillar larvae to the surface of the turf, where they can be easily counted. However, this method has not been used successfully with webworms, because the larvae are not as easily irritated by soap solutions as other caterpillar pests are.

To deal with some of these problems, a degree-day model was developed by Tolley and Robinson at Virginia Polytechnic Institute and State University. Using a lower developmental threshold temperature of 50°F, their model predicts the occurrence of peak adult moth flight activity, with the recommendation that applications for larvae be made 10 - 20 days after the peak adult flight. By predicting when small larvae will appear, this model gives superintendents the opportunity to use "softer" insecticides such as *Bacillus thuringiensis* and to gain better control of the larvae through more accurate timing of applications.

Which turf insects are most appropriate for degree-day studies? The examples above illustrate that degree-day models are most helpful when:

- insects are small and difficult to detect visually
- it is not feasible to monitor insect counts via black light, pheromone or other insect traps
- biological control products are used that target very narrow windows in the insect's life cycle

Degree-day models may not be helpful for all turf insects, however. For example, an insect such as the Japanese beetle is easy to detect visually, due to the large size and strong flight activity of the adult beetle. Once adults are observed, superintendents have learned to make applications against the larval grub stage 3–4 weeks later, with good results. In this case, a degree-day model would be redundant.

Validation and the role of golf course superintendents

Accumulating all of the biological and mathematical data necessary for development of a degree-day model takes several years of laboratory and field research to accomplish. Yet even once the model design is complete, the most important step in the development of a degree-day model has yet to be accomplished -- validating it under real-life conditions at several different golf courses. This process allows researchers to compare their predictions against actual insect populations, and to adjust the model if necessary.

For example, the black turfgrass ataenius model proposed by Wegner and Niemczyk was developed in Ohio, and predicts two generations per year. However, a two year black light trapping study conducted by PACE Turfgrass Research Institute in Southern California demonstrates that there are at least three generations of ataenius in this warmer climate. For the degree-day model to be useful in Southern California then, it would have to be adjusted to fit a three generation life cycle.

Unfortunately, few of the turfgrass insect degree-day models described in this article have been validated. The lack of validation is one of the key reasons that degree-day models are not more widely used on golf courses — their performance has not yet been proven.

This is where golf course superintendents come in. To get these valuable tools incorporated into your integrated pest management programs, superintendents, university researchers and consultants need to link up and form research partnerships. Through this type of cooperative arrangement, it should be possible to get insect degree-day models off of that dusty shelf in the laboratory and into the field where we can find out if they really work.

References

Tashiro, H. 1987. Turfgrass insects of the United States and Canada. Cornell University Press, Ithaca, NY. 391 pp.

Tolley, M.P., and W.H. Robinson. 1986. Seasonal abundance and degree-day prediction of sod webworm adult emergence in Virginia. J. Econ. Entomol. 79:400-404.

Wegner, G.S. and H.D. Niemczyk. 1981. Bionomics and phenology of *Ataenius spretulus*. Ann. Entomol. Soc. Amer. 74:374-384.

Wilson, L.T. and W.W. Barnett. 1983. Degree-days: an aid in crop and pest management. California Agriculture. 37:4-7.

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