3.8 HEAT ACCUMULATIONS

Fact Sheet Objectives

- Discuss the concept of heat accumulation and thermal time
- Explain methods for calculating and using heat accumulations

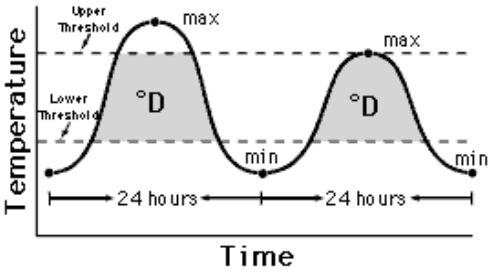

***Figure 1**. Illustration of the relationship between time and temperature and the accumulation of degree-days. One degree-day is one day (24 hours) with the temperature above the lower developmental threshold by one degree. For instance, if the lower developmental threshold for an organism is 10°C and the temperature remains 11°C (or 1° above the lower developmental threshold) for 24 hours, one degree-day is accumulated.*

Heat Accumulation Concepts

Temperature controls the developmental rate of many organisms. Plants, fungi and invertebrate animals, including insects and nematodes, require a certain amount of heat to develop from one point in their life cycles to another. This measure of accumulated heat is known as physiological time.

Theoretically, physiological time provides a common reference for the development of organisms. The amount of heat required to complete a given organism's development does not vary—the combination of temperature (between thresholds) and time will always be the same. Physiological time is often expressed and approximated on hourly or daily time scales using units of degree-hours (°hr) or degree days (°D).

Developmental Thresholds

Upper and lower developmental thresholds have been determined for some organisms through carefully controlled laboratory and field experiments. For example, the lower developmental threshold is 10.5°C and the upper developmental threshold is 32.2°C for the San José scale (*Quadraspidiotus perniciosus*). Thresholds vary with different organisms.

The lower developmental threshold for an organism is the temperature below which development stops. The lower threshold is determined by the organism's physiology. It is independent of the method used to calculate degree-days. The upper developmental threshold is the temperature above which the rate of growth or development begins to decrease or stop as determined by the **cut-off** method. The physiological interpretation of the upper threshold is dependent on the cut-off method.

Degree-Days

The total amount of heat required, between the lower and upper thresholds, for an organism to develop from one point to another in its life cycle is calculated in units called *degree-days* (°D). Sometimes called heat units, degree-days are the accumulated product of time and temperature between the developmental thresholds for each day.

Accumulated Degree-Days

Each developmental stage of an organism has its own total heat requirement. Development can be estimated by accumulating degree-days between the temperature thresholds throughout the season. Each crop or pest or species requires a defined number of degree-days to complete its development. The accumulated degree-days from a starting point can help predict when a developmental stage will be reached.

The date to begin accumulating degree-days, known as the Biofix date, varies with the species. Biofix dates are usually based on specific biological events such as planting dates, first trap catch, or first occurrence of a pest. Accumulation of degree-days should be done regularly, especially when a control action decision is near.

Heat Accumulation Calculation Methods

Although it is simple to calculate heat accumulations for a constant temperature in the laboratory, calculations with the daily temperature fluctuations that occur in nature is more difficult. Several methods have been used around the world to estimate degree-days through the use of daily minimum and maximum temperatures. All are approximations of the actual number of degree-days accumulated for a given set of daily temperatures and developmental thresholds, and therefore do not provide the exact degree-day values. While these have proved adequate under relatively consistent continental climatic conditions, they tend to fail under the irregular and unpredictable temperature conditions experienced in New Zealand's temperate maritime climate.

Some developmental relationships that require use of degree-hours have been determined. Accurate calculation of degree-hours requires a record of hourly temperatures rather than daily minimum and maximum temperatures. Even if hourly heat accumulations are not required, it is better under NZ conditions to calculate daily heat accumulations using hourly temperature data.

The degree-day calculation methods differ somewhat in complexity. Season and climatic region also cause these methods to vary in how accurately they reflect actual degree-days. Whichever method is used, it is important to use the same method as that used in developing the organism's biological growth relationships.

Useful Websites

UCLA guide to degree days:

http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html#Cutoff

http://ucce.ucdavis.edu/files/filelibrary/2028/23061.pdf

Journal of insect science – Codlin moth longevity:

http://www.insectscience.org/8.14/

Acknowledgements

The information in this factsheet was based in part on the information contained in the above UC Davis website.

Summary

- Heat accumulation calculations are critical in determining potential pest pressure
- Heat accumulation calculations (DD) should be used as part of any IPM programme
- Pre-emptive pest management can be utilised if DD monitoring predicts increasing pest pressure