Understanding and Using Heat Units

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Heat Unit Concept

Plants, insects and other "cold blooded" organisms lack the ability to maintain constant internal temperatures. As a result, their rates of growth and development are closely related to temperature changes in their respective environments.

The heat unit concept was initially developed to study plant-temperature relationships and to provide a method for more precisely measuring the intervals between growth stages (i.e. emergence to first bloom). The method typically used for calculating accumulated heat units is expressed as follows (3,7):

$$\text{Daily Heat Units} = AT - BT$$

Where: AT = Average Daily Temperature $\left(\frac{Tmax + Tmin}{2}\right)$

BT = Base Temperature (below which no growth occurs).

The heat unit concept is based on the assumptions that (a) growth or development occur only when the average daily temperature (AT) exceeds the base temperature (BT), (b) within certain temperature limits (about 60° F to 100° F for cotton) there is essentially a linear relationship between growth or development and daily heat unit accumulations, and (c) the number of accumulated heat units between growth stages for a given species is constant across years, locations, and climates (18,25,26).

Studies have been conducted to determine the most appropriate BTs for various crops. Several different BTs have been proposed and used by cotton researchers (9,19,21,22). Overall, the 60° F BT has gained the widest use. In 1983, Extension cotton specialists from the cottonbelt states formally selected 60° F (Degree Day 60° F) as the standard BT for use in cotton heat unit models.

Other modifications to the standard heat unit equation have been suggested and used. Some include components that make corrections for growth changes due to excessively high temperatures or other environmental factors (4,10,17) whereas others refined the calculation of daily heat unit accumulations (1,11).

Numerous criticisms have been suggested for the heat unit concept and these include (25,26):

a. All factors influencing plant growth and development have been reduced to one single environmental variable--temperature; this is an over simplification of the many complex physical, physiological and biochemical processes that are actually occurring.

b. A linear relationship between temperature and plant growth and development is assumed whereas, it's actually more apt to be curvilinear.

c. A constant base temperature is commonly used for an entire growing season whereas the base values are actually likely to be different for the various growth stages of the crop.

d. The number of accumulated heat units between growth stages for a given crop or variety is assumed to be constant but is actually likely to vary somewhat between locations and years due to the influence of various environmental variables (Tables 1 and 2).

Despite these valid criticisms, the heat unit concept has found application in numerous cropping systems and related industries. The system has been used by producers, processors, merchants and scientists in practical farm applications, for scheduling work forces and the flow of raw materials, in projecting commodity market fluctuations and in conducting research studies.

Table 1. Variations in heat unit schedules for cotton at 6-locations in the U.S.*

Growth Stage	Heat Units Required San J. Valley Calif.	Ariz	El Paso Tx**	Lubbock Tx	Stone-ville Ms	Green-ville Ms
Planting to:						
Square	500	-	571	584	-	-
Bloom	830	920 (266)	880	994	937	957
Open Boll	1780	-	1575	1682	2150	1986
Maturity	2700	4900	(2200)	(2200)	(2800)	-
Sq. to Bl.	330	-	309	410	-	-
Bl. to Open Boll	950	-	695	-	-	1024

*Data summarized from the following references: 9, 21, 33, personal communication, Dr. Gary Barker, USDA-ARS Agricultural Engineer, Lubbock, TX
**BT=55° F; all other BT=60° F

Table 2. Variation in heat unit schedules for cotton planted on different dates in Lubbock in 1983.*

Planting Date	Planting to: Square Days	Square Hu	Flower Days	Flower Hu	Open Boll Days	Open Boll Hu	Termination Days	Termination Hu
5/14	45	549	67	988	102	1670	128	2117
5/27	39	522	63	1001	100	1722	121	2066
5/29	35	545	56	941	93	1664	113	1983
6/5	35	633	52	974	97	1641	106	1945
6/11	33	628	53	1029	88	1704	100	1871
6/18	32	627	53	1030	88	1696	93	1756

*Unpublished Data. Dr. Gary Barker, USDA-ARS Ag Engineer. 1984
HU=AT-BT; BT=60° F

Uses in Cotton Production Systems

The dominant applications of heat units with regard to cotton production have been in predicting crop growth and development (5,12,14,15,20,27,28,29,33) El-Zik and Sevacherian (9) developed a model based on heat unit accumulations from the date of planting to project the initial appearance and/or development of cotton fruiting parts. The basic heat unit schedule (Table 3) developed by these workers is now widely used as a standard for monitoring the growth and development of cotton.

Table 3. Heat unit schedule for Acala cotton development in the San Joaquin Valley, California.*

Stages of Plant Growth	Calendar Days Range	Calendar Days Average	Degree Days Above 60° F Required
Planting to Emergence	4-30	8	50
Emergence to Squaring	35-45	40	450
Emergence to First Bloom	57-70	65	780
Emergence to First Open Boll	113-128	120	1730
Normal Crop Production	155-185	170	(2800)

*Reference 11

Recently, these same authors developed a slide rule-type crop and insect management guide based on accumulated heat units (8,23). This guide is intended to help producers make critical and timely decisions regarding various management decisions including irrigation and insect control measures.

Other useful applications with regard to cotton production include defining relationships between accumulated heat units and (a) lint yields (5,15,19,21,22), (b) insect activities (10,13), (c) disease activities (6), (d) adjustments in cultural practices (16), (e) timing growth regulator treatments (2) and (f) timing harvest-aid chemical application (24).

Use on the Texas High Plains

In short season production areas such as the Texas Plains and Oklahoma, temperature is frequently a limiting factor in crop production. On the Texas High Plains, long term average heat unit accumulations for the growing season range from about 1800 to 2400 (Table 4). Approximately 2200 to 2400 heat units are required for optimum production.

Table 4. Long term heat unit accumulations at 12 locations on the Texas High Plains.*

Location	Accumulated Heat Units	Location	Accumulated Heat Units
Bailey	1818	Lamb	1904
Briscoe	1793	Lubbock	2210
Castro	1623	Lynn	2198
Dawson	2452	Parmer	1725
Floyd	2126	Terry	2124
Gaines	2355	Yoakum	2016

*Base temperature = 60° F; from May 1 to September 30. Data provided by Dr. Bill Dugas, Extension Meteorology Specialist, Temple, Texas.

Obviously, even in this rather confined geographical area, cultural practices have to be adjusted for the normal variations in growing conditions between counties. Yet, there is considerable year to year variation in seasonal heat unit accumulations. To some extent, producers can take advantage of these fluctuations by adjusting inputs (i.e. fertilizer, water) based on the outlook for the current growing season.

Presently, portable weather stations that record air temperature, soil temperature, relative humidity, radiation, rainfall and wind speed are located in the counties listed in Table 4. Data from these units and from U.S. Weather Service reporting stations are used to develop weekly agricultural weather advisories by Dr. William A. Dugas, Agricultural Meteorology Specialist at the Blackland Research Center in Temple.

The advisories provide updates on heat unit accumulation in addition to information about rainfall probabilities, probable rate of moisture utilization by crops etc. By comparing current seasonal heat unit accumulation with those of previous years (Figure 1). Producers can at least confirm their own impressions about the rate of crop development and make decisions about adjusting crop inputs.

In 1984, for example, growing conditions in May and June were exceptional and the above average heat unit accumulations (Figure 1) reflected the rapid crop development. In view of the favorable crop prospects, additional inputs appear to be warranted, even in the northern counties which typically have the shorter growing seasons.

Use in Crop Termination

In 1980, Wanjura and Newton (30,31,32) published a lint development model designed to estimate the extent of fiber development at any time during the boll development period. Among other things, the model can be used to predict when the crop is ready for defoliation or desiccation. The model makes these predictions based on date of bloom initiation, time required to set the crop and average daily temperatures.

Accurate predictions of crop maturity are important because late rains and cool temperatures can delay normal boll opening. Often, producers are hesitant to apply harvest-aid chemicals to a slow opening crop for fear of prematurely terminating lint development. As a result, the opportunity for a timely harvest with minimal weathering losses may be missed.

The lint development model is designed to predict the extent of crop maturity and could be used to time the application of growth regulators such as Prep, and of defoliants or desiccants. Further testing of this model will be conducted in the central Texas area in 1984 and it will also be used to time the applications of harvest-aid chemicals in demonstrations on the Texas High Plains.

Conclusion

Heat unit models provide a relatively simple means for monitoring the physiological development of crops and adjusting cultural practices to correspond to the favorableness of the growing season. These models are not designed or intended to make management decisions but merely to serve as an aid in making better and more timely decisions.

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