POTENTIAL HEAT UNIT (PHU) PROGRAM

The potential heat unit program will calculate the total number of heat units required to bring a plant to maturity using 1) long-term maximum and minimum temperature data, 2) the base or minimum temperature required by the plant for growth, 3) and the average number of days for the plant to reach maturity. A description of plant heat units follows the directions for installation and program use.

To install:

This program is designed to be installed from a diskette, so a few extra steps are required.

1) Download phuinstall.zip.
2) Extract installation files contained in phuinstall.zip and copy to diskette.
3) Open MSDOS command prompt window, change to diskette drive and type `install.exe`
4) The installation program will offer the option of installing 2 different software packages. You will want to choose the first package (EPIC PHU program). The next prompt screen will ask you to specify the diskette drive and the installation drive and directory. Use the arrow keys to move from field to field and press the ENTER key to start the installation process.

To run:

This program runs in the MSDOS mode. You will need to open a MSDOS command prompt window and move to the directory where the PHU program is installed to operate the UTIL interface and execute the program.

Build weather input file:

1) At the command prompt, type `util phuplt` and press the ENTER key.
2) The UTIL editor will open and will display the data fields. Three types of information are required: the latitude of the watershed and average monthly maximum and minimum temperatures. For watersheds in the United States, an autoload feature is included that will extract the required data from the default U.S. weather generator database.

   To use the autoload:

a) Type `locweat 41 72` (where `41` is replaced by the latitude and 72 is replaced by the longitude of your location) and press the ENTER key.
b) A list of weather stations in the database is displayed. The weather station closest to the specified latitude and longitude is listed first. Use the arrow keys to move up and down the list. Select a weather station by pressing the ENTER key when the desired weather station is highlighted.
c) The weather data is loaded into the editor.

If custom weather generator files are being used in a simulation, the user should do the following:

a) Enter the mean monthly maximum and minimum temperature from the custom weather generator file and the latitude of the watershed.
b) Type any comments about the data on the first line of the file.

3) Save the file by pressing the F4 key and entering a file name (e.g. co1.wth).
4) Exit the UTIL editor by pressing the F3 key.

Provide plant growth information:

1) To view the plant growth file, type `util phucrp`
2) A list of plants is displayed. For each plant, the following information is provided: the season in which the plant grows (summer or winter, i.e. warm season or cool season), the optimal and minimum temperature for plant growth, the amount of dry-down the plant undergoes prior to harvesting, and the number of days required for the plant to reach maturity or the number of days between planting and harvest.
3) Make sure that the plant of interest is listed. If it is not listed, add the plant to the file. The season in which the plant grows, and the optimal and minimum temperature for plant growth can be obtained from the plant growth database (crop.dat). The amount of dry-down and the number of days required for the plant to reach maturity are a function of the plant variety. The length of the growing season may be listed for up to 5 different varieties of a plant species.

> *Comment*: Note that the number of days to maturity for pine is 7300. For modeling purposes, the value for number of days to maturity for trees should be replaced with the growing season for the plant, i.e. the number of days between budding and leaf senescence.

4) If changes were made to the file, save the file by pressing the F4 key.
5) Exit the UTIL editor by pressing the F3 key.

Obtain results:

1) At the MSDOS command prompt, type `phu`
2) The program will ask for the name of the weather data file. Type the name of the file and press the ENTER key.
3) The program will write the name of the output file to the screen. Once the program terminates, open the output file with an editor.
4) For each plant listed in the phucrp.dat file, the following information will be given:

```
CROP    CROP   VARIETY
 NO.    NAME     NO.          #1         #2         #3         #4         #5
 1   soybeans     1       120.00     115.00     110.00     105.00     100.00
                           1551.      1476.      1401.      1326.      1251.
                             .02        .02        .02        .02        .02
                               8          8          8          8          8
```

The first line lists the days to maturity for the variety. The second line lists the total heat units required to bring the plant to maturity in the watershed. The third line provides the time of planting by heat unit scheduling and the fourth line provides the time of planting by Julian date.

EXPLANATION OF HEAT UNITS

(Excerpted from SWAT 2000 manual, Chapter 17)

Temperature is one of the most important factors governing plant growth. Each plant has its own temperature range, i.e. its minimum, optimum, and maximum for growth. For any plant, a minimum or base temperature must be reached before any growth will take place. Above the base temperature, the higher the temperature the more rapid the growth rate of the plant. Once the optimum temperature is exceeded the growth rate will begin to slow until a maximum temperature is reached at which growth ceases.

In the 1920s and 1930s, canning factories were searching for ways to time the planting of sweet peas so that there would be a steady flow of peas at the peak of perfection to the factory. Crops planted at weekly intervals in the early spring would sometimes come to maturity with only a 1- or 2-day differential while at other times there was a 6- to 8-day differential (Boswell, 1926; 1929). A heat unit theory was suggested (Boswell, 1926; Magoon and Culpepper, 1932) that was revised and successfully applied (Barnard, 1948; Phillips, 1950) by canning companies to determine when plantings should be made to ensure a steady harvest of peas with no "bunching" or "breaks".

The heat unit theory postulates that plants have heat requirements that can be quantified and linked to time to maturity. Because a plant will not grow when the mean temperature falls below its base temperature, the only portion of the mean daily temperature that contributes towards the plant's development is the amount that exceeds the base temperature. To measure the total heat requirements of a plant, the accumulation of daily mean air temperatures above the plant's base temperature is recorded over the period of the plant's growth and expressed in terms of heat units. For example, assume sweet peas are growing with a base temperature of 4.5°C. If the mean temperature on a given day is 20°C, the heat units accumulated on that day are 20 – 4.5 = 15.5 heat units. Knowing the planting date, maturity date, base temperature and mean daily temperatures, the total number of heat units required to bring a crop to maturity can be calculated.

The heat index used by SWAT is a direct summation index. Each degree of the daily mean temperature above the base temperature is one heat unit. This method assumes that the rate of growth is directly proportional to the increase in temperature. It is important to

keep in mind that the heat unit theory ignores the impact of harmful high temperatures. It assumes that all heat above the base temperature contributes to crop growth.

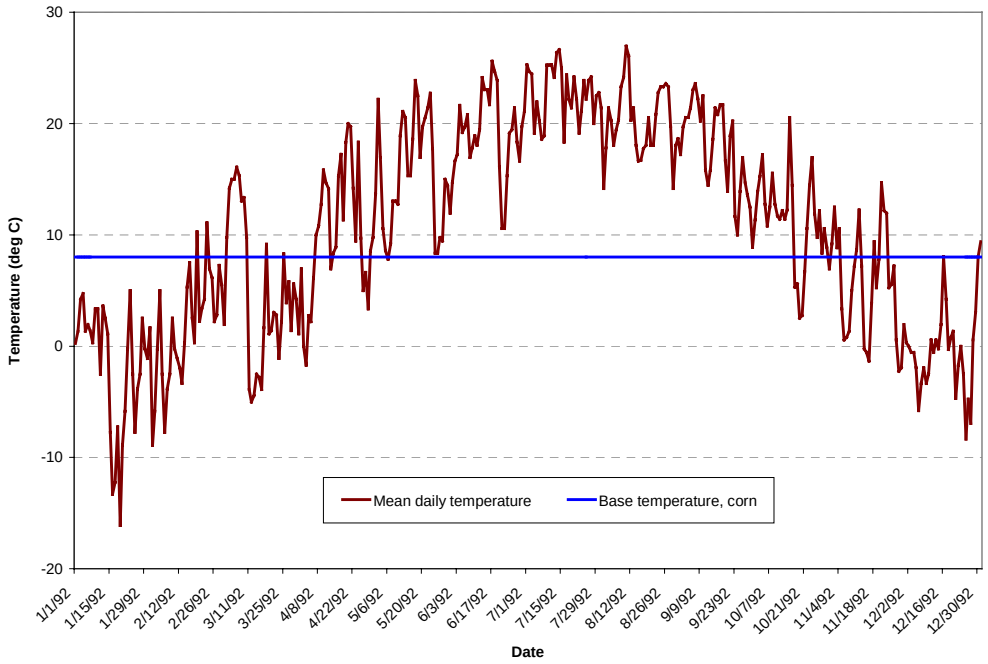


Figure 17-1: Mean daily temperature recorded for Greenfield, Illinois

The mean daily temperature during 1992 for Greenfield, Illinois is plotted in Figure 17-1 along with the base temperature for corn (8°C). Crop growth will only occur on those days where the mean daily temperature exceeds the base temperature. The heat unit accumulation for a given day is calculated with the equation:

$$HU = \overline{T}_{av} - T_{base} \qquad \text{when} \quad \overline{T}_{av} > T_{base} \qquad 17.1.1$$

where HU is the number of heat units accumulated on a given day (heat units), $\overline{T}_{av}$ is the mean daily temperature (°C), and T_{base} is the plant's base or minimum temperature for growth (°C). The total number of heat units required for a plant to reach maturity is calculated:

$$PHU = \sum_{d=1}^{m} HU \qquad 17.1.2$$

where PHU is the total heat units required for plant maturity (heat units), HU is the number of heat units accumulated on day d where d = 1 on the day of planting and m is the number of days required for a plant to reach maturity. PHU is also referred to as potential heat units.

When calculating the potential heat units for a plant, the number of days to reach maturity must be known. For most crops, these numbers have been quantified and are easily accessible. For other plants, such as forest or range, the time that the plants begin to develop buds should be used as the beginning of the growing season and the time that the plant seeds reach maturation is the end of the growing season. For the Greenfield Illinois example, a 120 day variety of corn was planted on May 15. Summing daily heat unit values, the total heat units required to bring the corn to maturity was 1456.