Overview of PhenologyMMS 1.3

PhenologyMMS 1.3 is a software program designed to simulate the phenological *development* of certain crops. Phenology is the sequence or timing of developmental stages or events and is essential to understanding crop development and *growth*. Many users and farmers in particular need this information as many management decisions are based on the growth stage of the crop. This helps to enhance economic crop yields and at the same time maintain environmental quality. For example, as water for agriculture becomes increasingly more limited it will be critical to know the developmental stage the crop is at so the grower knows when the best times are to apply water. Simulation models and decision support tools also benefit by having crop simulation models which predict the timing of *growth stages*.

Plant development is orderly and predictable, (Rickman and Klepper, 1995; McMaster, 2005) and the plant's genetics determines the sequence of the growth stage events (Distelfeld et al., 2009; Moragues and McMaster, 2012). Environmental conditions also influence the plant's development rate and includes such things as temperature, water availability, nutrients, *photoperiod*, etc. (White et al., 2008). Temperature has been used most frequently to predict the timing of developmental events and often uses some measurement of *thermal time*. Another very important influence on crop development is water availability, however many models do not include this impact on development. “Confounding the problem of variable phenological responses to water deficits is that for most crops the complete *developmental sequence* of the *shoot apex* has not been completely summarized and quantified or correlated with readily observable developmental stages.”(McMaster et al., 2013).

PhenologyMMS 1.3 employs temperature as thermal time and water stress to predict the development of the crop and the timing of phenological growth stages.

Install PhenologyMMS 1.3 to begin using the model.

Links to: Install PhenologyMMS 1.3
Launch PhenologyMMS 1.3
Run PhenologyMMS 1.3

Installation Instructions

To install PhenologyMMS click on the following link to go to the website where you will be able to download the model: *link*

Links to: Overview of PhenologyMMS 1.3
Launch PhenologyMMS 1.3
Begin Setup
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Run PhenologyMMS 1.3
Output

Launch PhenologyMMS 1.3

Install the model and double click the desktop *icon* to launch the program.

The first screen to appear is the *PhenologyMMS 1.3* Flash Screen or Welcome Screen which simply shows the name of the model and the authors.

It is displayed for about 2 seconds and then disappears allowing the Begin Setup screen to display.

Links to: Overview of PhenologyMMS 1.3
Set Inputs
Run PhenologyMMS 1.3
Output

How to Run PhenologyMMS 1.3

First be sure to set up the program to *Run* for the crop and location you wish to simulate. This is done via the Begin Setup and the Set Inputs screens.

To Run or execute the PhenologyMMS program, click on the Run button located on the Begin Setup, Set Inputs, Temperatures or the Growth Stages screens. This will execute the program and open the Output window.

Within the Output window, you can see the inputs to the program. The *leaf number* table and the *phenology table* which resulted from the run are also displayed in the Output window.

From the Output screen, you have the option to Save the Scenario or setup for this run and to Save the Output from this run.

Begin Setup

The Begin Setup Screen appears when the Welcome screen closes. It is in this screen that very basic choices are selected. This includes the Crop and the Location Weather files. You can *run* the model with just these two selections if you are happy with the default values for the other selections found in the Set Inputs screen, Temperatures screen and the crop's *Growth Stages* screen.

Choose Crop – select the crop you wish to simulate by clicking the down arrow on the Crop drop-down box. The list includes all the crops for which *PhenologyMMS 1.3* has been parameterized.

Select Location *Weather File* – click on the down arrow on the drop down box and choose a weather file from those listed. Generally, the naming convention is *the city_state* (2 letter code for the state*)_beginning year and ending year* of data. For example, 'Akron_CO_1813' indicates that there are data from 1918 to 2013 for Akron, Colorado.

NOTE: If you add a weather file to the MMSWeather folder while you are running PhenologyMMS 1.3, the weather file will not be visible in the drop down list. You must close the program and restart it for the newly added file to be visible. Be sure the new file has the .dat extension.

Click here for help on the structure of the weather files and how to add a new weather file.

Saved Scenarios
The 'Load Saved *Scenario*' button - If you would like to re-run a previously saved scenario, click on the drop down arrow box near the 'Load Saved Scenario' button. That will display a list of all saved

scenarios. Click on the scenario to be re-run and then press the ‘Load Saved Scenario’ button. If you have selected a scenario that runs a different crop than that selected or uses a different weather file, these changes will appear in the Choose Crop drop down and in the Location/Weather Files drop down boxes.

To Save a Scenario, you will do this from the Output screen via the ‘Save Scenario…’ button. If you save a scenario after a run and come back to the Begin Setup screen, the newly saved scenario will not be visible in the drop down box. You will need to close the program and re-start it for the file to appear. CAUTION: Make sure to add the extension ‘.dat’ to the file name when saving it or it will not be visible in the saved scenarios list the next time you open the program.

The ‘Help’ button - accesses the Help System.

The ‘Disclaimer…’ button - displays the USDA-ARS disclaimer statement: “USDA-ARS MAKES NO REPRESENTATION NOR EXTENDS ANY WARRANTIES OF ANY KIND, EITHER EXPRESS OR IMPLIED, OF MERCHANTABILITY or FITNESS OF THE INFORMATION IN OR PRODUCED BY THE PHENOLOGYMMS SOFTWARE FOR ANY PARTICULAR PURPOSE, OR THAT THE USE OF THE INFORMATION WILL NOT INFRINGE ANY PATENT, COPYRIGHT, TRADEMARK, OR OTHER INTELLECTUAL PROPERTY RIGHTS, OR ANY OTHER EXPRESS OR IMPLIED WARRANTIES.”

Three buttons below the picture are used to navigate to other screens. These include: ‘Set *Inputs*…’, ‘Set Growth Stages…’ and ‘Run…’.

The ‘Set Inputs …’ button - opens the ‘Set Inputs’ screen where planting information is entered. Default values load with the program so you can simply accept these values or further customize them for your location.

The ‘Set Growth Stages…’ button - opens the ‘Set Growth Stages’ screen and displays the *growing degree-days* (*GDD*) parameters for each growth stage for Non-Stressed conditions (*GN*) and for Stressed conditions (*GS*). Parameters for *Number of Leaves* for each growth stage are also given for Non-Stressed (*LN*) conditions and for Stressed (*LS*) conditions.

The ‘Run…’ button - causes the program to run displaying output in the Output Screen.

Weather/Location Files

A.A. The Structure of a *Weather File* – A *location weather file* contains data for a specific number of years/days and includes at the least, precipitation and temperature data. PhenologyMMS can *run* with just these two weather variables. Additional climate *inputs* may be included in the file if available.

1. Precipitation (precip) – This is the daily precipitation for each day of the weather record. Depending on the location, many days will be 0.0. The units are in mm.
2. Temperature -
   a. *Maximum Temperature* (*Tmax*) – This is the day's recorded maximum temperature. It is provided in °C.
   b. *Minimum Temperature* (*Tmin*) – This is the day's recorded minimum temperature. It is provided in °C.
3. Solar Radiation (*Solar Rad*) – This is the light and energy that comes from the sun, i.e. sunlight. The required units for PhenologyMMS are megajoules/meter^2 (MJ/m^2).
4. Soil temperature at 5 cm – This is the maximum soil temperature at 5 cm.
5. Calendar Year – This is simply the calendar year of the data, e.g., 2004; not the number of the year of the data in the data file at a point in time, i.e. 1, 2, 3, etc.
6. Day of Year – The day in the year of observation, e.g. 150, that corresponds to the date, May 30, in a non-leap year.
7. Additional columns are included in the supplied weather files as these are also used for another model which requires these columns. These are for the day, month and year. This year is not the calendar year; it is the number of the year in the sequence of years within the weather file.

B.

B. How to Add a Weather File.

1. Construct the weather file with the following order of data columns:
   a. Day – 1 to 28, 29, 30 or 31, whichever is appropriate for the month and year.
   b. Month – 1 to 12
   c. Year – year within the weather file sequence of years; 1, 2, 3, … .
   d. Precip – daily amount of rainfall in mm.
   e. Tmax – Maximum daily temperature in °C.
   f. Tmin – Minimum daily temperature in °C.
   g. Solar Rad – sunlight in MJ/m^2. MJ = *megajoules* .
   h. Year – calendar year, e.g., 2004.
   i. *DOY* – *Day of year*, i.e., the sequentially numbered day from Jan. 1 to the day in the date of interest.
   j. SoilTemp – the day's maximum soil temperature at 5 cm depth in °C.
2. Unit Conversions:
   a .To convert between units of precipitation:
      i. 1 cm = 10 mm; 1 inch (in) = 25.4 mm
      ii. cm * 10 = mm; in * 25.4 = mm
      iii. Trace amount of precip = 0.01 in = 0.254 mm
   b. To convert between *Fahrenheit* (°F) and *Celsius* (°C):
      i. °C = (°F – 32) * 5/9

ii. °F = 9/5 °C + 32

c. To convert between MJ/m² and Langley's/day

i. 1 MJ/m² = 23.895 Langley's/day

ii. Example: 50 MJ/ m² = 50 * 23.895 = 1194.8 Langley's/day.
350 Langley's/day = 350/23.895 = 14.6 MJ/m²

d. Fill the spreadsheet with data. Even though there are columns in the file not needed by PhenologyMMS, they are read in and, therefore these columns must be present in the file.

3. How to Handle Missing Data

a. Very often data are missing in the weather record. If the number of consecutive days is not too large, data can be interpolated to fill in data that are missing for temperature and *solar radiation*. Precip is much harder to fill in.

b. To fill in by *interpolation* find the difference between the day before and the day after the missing block of data. Then divide that amount by the number of missing days plus 1. Depending on whether the values are increasing or decreasing as observed from the day before and the day after the missing days, add or subtract the calculated value from the day before the missing block of data. Then using that value add or subtract the calculated value to be added (or subtracted) to/from the previous filled in day and so on throughout the missing block of data. The number of days of missing data that can be filled in by this method should not be a large amount. You may want to determine how many days can be filled in but it should not be larger than 30 days and less is probably better. For larger blocks of data it is better to enter 999.9 for those missing data or try to get data from a nearby weather station.

c. Precip is a difficult climate variable to estimate because it doesn't rain daily as temperature always has a daily value. Also, the amount of precip when it does occur can be quite variable. Generally, we simply entered 999.9 to indicate a missing value.

d. Another possible way to fill in missing Precip values is to find a weather station close by to the area of interest and fill in with data from that station, if available.

e. A good source of weather data can be found at the NCDC (National Climate Data Center) at the NOAA (National Oceanic and Atmospheric Administration) website. http://www.ncdc.noaa.gov/cdo-web/search#t=secondTabLink. These data are free unless you require them to be certified. (This is usually required when a court has subpoenaed climatic records.) You can select the climate items you want and the period of time for which you want data however, there are often a limited number of climate variables included. Usually, there are more than one climate station and one may be able to piece together a good weather record from one or more stations for the location in question.

Set Inputs

The Set Inputs Screen contains basic planting information. The information in this screen can be changed if the default values do not apply to your location/setup, or if you want to explore what might happen with different input values.

Planting Date - Most likely you will want to change the date. Enter it in the format of mm/dd/yyyy.

Soil moisture -This always defaults to *Optimum* , but there are three other choices. These include *Medium* , *Dry* and *Planted In Dust*. These are simply general descriptive terms to describe the soil moisture at the time of planting which is used in predicting *emergence* of the crop. Within the model, these terms are converted to a numerical representation for the soil. While these values have specific ranges of soil moisture (not shown), for most purposes each category is intended to represent general planting conditions. A simple algorithm within the program will use rainfall events to increment the category chosen to a greater soil moisture condition, but the category does not decrease due to evaporation. For more information regarding emergence in the model, please refer to Emergence in PhenologyMMS.

Planting Depth - This is entered in centimeters (cm) and affects only the time of *seedling* emergence.

Planting Rate (pounds/square meter) - This is also available for editing, although currently this input does not affect the timing of any phenological event.

Latitude - Enter the value for your location in degrees, e.g., 40.165. Values that are positive are located in the Northern Hemisphere while negative values are located in the Southern Hemisphere. In the future, this will be used in determining the *photoperiod* effect for a crop but, it is not currently implemented.

Maximum *Canopy Height* - This is entered in centimeters (cm) and is the maximum potential canopy height under optimal conditions, for the crop being simulated. Please note: the final plant height predicted by the model is not influenced by any stresses (e.g., water stress).

Several buttons are available below the picture for screen navigation:

The 'Close and Save' button - closes this window and returns to the previous screen (i.e., 'Begin Setup' screen). It also saves the information on this screen.

The 'Reset' button - resets the values back to the original default values.

The 'Temperatures' - button opens the 'Temperatures' screen where temperature and other values are presented. ***However, it is strongly recommended that the information in this screen is not changed as changing these values will negatively influence the program***. They are presented here for information purposes only.

The '*Run*…' button - runs the program and displays output in the Output screen.

The 'Help…' button - accesses the Help System.

Emergence

Germination and *emergence* are predicted based on the accumulation of *thermal time* and soil moisture based on the *SHOOTGRO* model (Wilhelm et al., 1993. Ecological Modelling 68:183-203 203). Four soil water levels are available and the user *inputs* the condition at planting time. The *GDD* required for germination increases and the *elongation* rate decreases as water content decreases. After planting, precipitation can shift the soil moisture condition upwards toward *Optimum* but there is no provision reducing the soil moisture level due to evaporation.

The four soil moisture levels are: Optimum, *Medium*, *Dry* and *Planted in Dust*. These are shown in Table 1 below which is found in the reference cited above (Ref. 3, Table 2). Other input parameters include the lower and upper *Water-filled pore space* (*wfpslo* and *wfpsup*), Germination time (*germgdd*), and *Elongation rate* (*ergdd*).

Daily precipitation is read in from the *weather file* and is given in mm.

Seeds planted in soil water conditions considered to be ‘Planted in Dust’ are assumed to not begin the germination process until some minimal soil water level is reached (i.e., 'Dry' conditions). Therefore, seeds Planted in Dust must move up to the Dry soil moisture level before beginning the accumulation of thermal time required for germination. At least seven mm or more of precipitation must be received before soil moisture can move from Planted in Dust to Dry conditions.

In order to provide a more realistic process of germination, two intermediate soil moisture levels were added. These occur between Optimum and Medium and between Medium and Dry. These were necessary because germination was occurring too rapidly with only the four soil moisture conditions named above.

Once germination has occurred, the elongation rate of the *coleoptile* (ergdd) is increased based on the input elongation rate in mm per growing degree-day for the soil moisture condition. This value is multiplied by the day’s growing degree-day value and added to the elongation amount already achieved. Once the elongation length is greater than the *planting depth*, emergence has occurred.

TABLE 1 (from Ref. 3 Table 2)

Seed germination and *seedling* elongation rates for several broad categories of seedbed conditions.

Seedbed condition	Water-filled pore space (%)	Germination time (GDD^a)	Elongation rate (mm GDD^{-1})
Optimum	> 45	80	0.50
Barely adequate	35-45	90	0.40
Dry	25-35	110	0.33
Planted in Dust	<25	-	-
		[a]GDD = growing	

		degree-day (base 0°C)	

Links to: GDD Methods
Temperatures
Weather/Location Files

GDD Methods

There are many methods used to calculate *growing degree-days* (*GDD*). PhenologyMMS provides four methods, although default parameters for each crop are available for only one specific method. For example, parameters for Method 1 are provided for winter wheat while parameters for Method 2 for are provided for corn. A description of each of the Methods follows.

GDD Method 1 - this is a very common and simple method of calculating GDD. GDD is calculated by summing the daily *maximum temperature* (*Tmax*) and the daily *minimum temperature* (*Tmin*), dividing that result by two to estimate the daily average temperature (*Tavg*), and then subtracting the *base temperature* (*Tbase*) from Tavg. Tbase is the temperature below which the process of interest does not progress.

Tavg = ((Tmax + Tmin)/2)

GDD = (Tavg - Tbase)

Note: GDD >= 0 (i.e., cannot be negative). If the GDD value is less than zero, it is set equal to 0.0.

Method 1 is commonly used for small grains such as wheat, barley and millet.

GDD Method 2 - this method is a slight variation of *GDD Method* 1. The differences are: a) adding an upper temperature threshold (*Tupper*), which limits the amount of GDD that can be accumulated for the day, and b) adjusting Tmax and Tmin for each day based on the base (Tbase) and upper (Tupper) thresholds as follows. Both Tmax and Tmin are compared to Tbase and if Tmax and/or Tmin is less than Tbase then Tmax and/or Tmin is set equal to Tbase. Likewise, if Tmax and/or Tmin is greater than Tupper, then Tmax and/or Tmin is set equal to Tupper. The average temperature is calculated and Tbase is subtracted from Tavg. If the resulting value is less than zero, then it is set to zero.

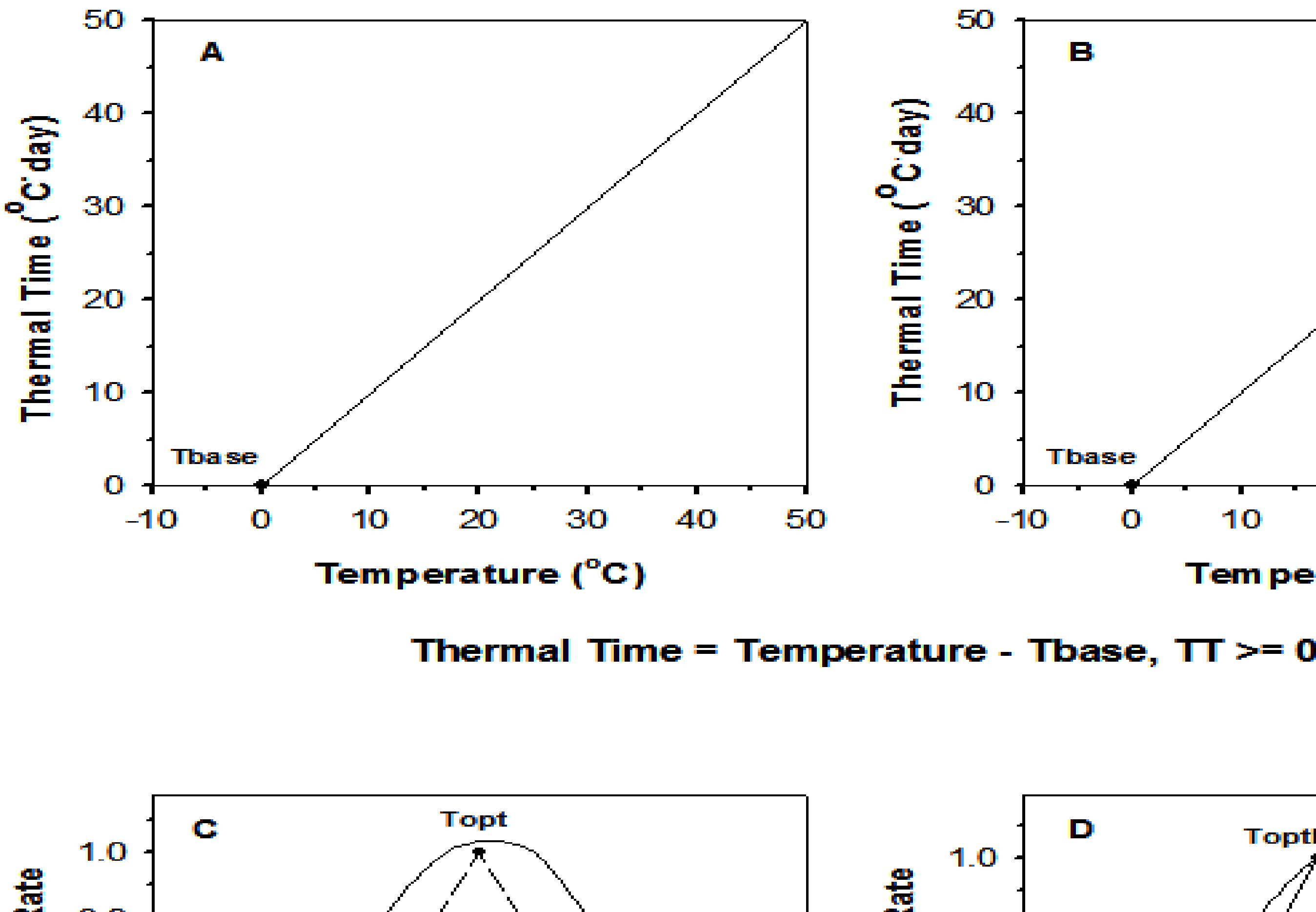
Method Two is used for Corn, Sunflower, Sorghum and Dry Beans.

GDD Method 3 - this method employs a two-segmented linear model. The first segment extends from Tbase to an Optimum Temperature (*Topt*), and the second segment extends from Topt to Tupper. The Average temperature is calculated and compared to Tbase and Topt. If Tavg is greater than or equal to Tbase and less than or equal to Topt, then a temperature factor (*tf*), which uses the slope of the first segment of the line, is calculated and multiplied by the value of Tavg minus Tbase. This gives the GDD value for the day. However, if the Tavg is greater than Topt and less than or equal to Tupper, then 'tf', which uses the slope of the second segment of the line, is multiplied by the value of Tavg minus Tbase to give today's GDD value. If neither comparisons are true and Tavg is less than Tbase or greater than Tupper, then the GDD for the day is zero.

GDD Method 4 - this method uses a three-segmented linear model. The first segment extends from Tbase to the *Lower Optimum Temperature* (*Toptlo*); the second segment from Toptlo to the *Upper Optimum Temperature* (*Toptup*); the third segment runs from Toptup to Tupper. The Average temperature (Tavg) is calculated and compared to Tbase and the Lower Optimum Temperature (Toptlo). If Tavg is greater than or equal to Tbase and if Tavg is less than Toptlo, then Tbase is subtracted from Tavg. This value is multiplied by the calculated temperature factor, 'tf' which is calculated using the slope of this first segment of the line to get the GDD value for the day. However, if Tavg is greater than or equal to Toptlo and less than or equal to Toptup, then Tbase is subtracted from Tavg and that value is multiplied by 'tf' which has been calculated using the slope of the second line segment (which is 1). This gives the GDD value for the day. If Tavg is greater than Toptup and less than or equal to Tupper, then 'tf' is calculated using the slope of this third segment of the line and is multiplied by the result of Tavg minus Tbase to yield the GDD value for the day. If none of the situations are true and Tavg is less than Tbase or greater than Tupper, then GDD for the day is set equal to zero.

All methods calculate *thermal time* as described above, however Methods 3 and 4 add another modifier to the thermal time calculation which assumes that not all temperatures between Tbase and the maximum temperature have the same effect on plant development. For example, temperatures at the optimum level (Method 3), or in the optimum range (Method 4) result in faster development than those near Tbase or the maximum temperature. Therefore, the calculated thermal time is then reduced by the 0-1 development rate factor (shown on the y-axis) to calculate the final thermal time for the day. Adding this development rate factor is often considered theoretically more correct, but often in practice for field conditions does not result in significant improvement in accuracy for many reasons. Further, it adds additional parameters for optimum temperature (or range) and uses a simple linear relationship. The figures for Methods 3 and 4 also show a curvilinear relationship for calculating thermal time and the development rate factor, but this approach has not been incorporated into PhenologyMMS.

GDD Methods Figure (McMaster, G. S. 2009. Development of the wheat plant. page 44.) **-**

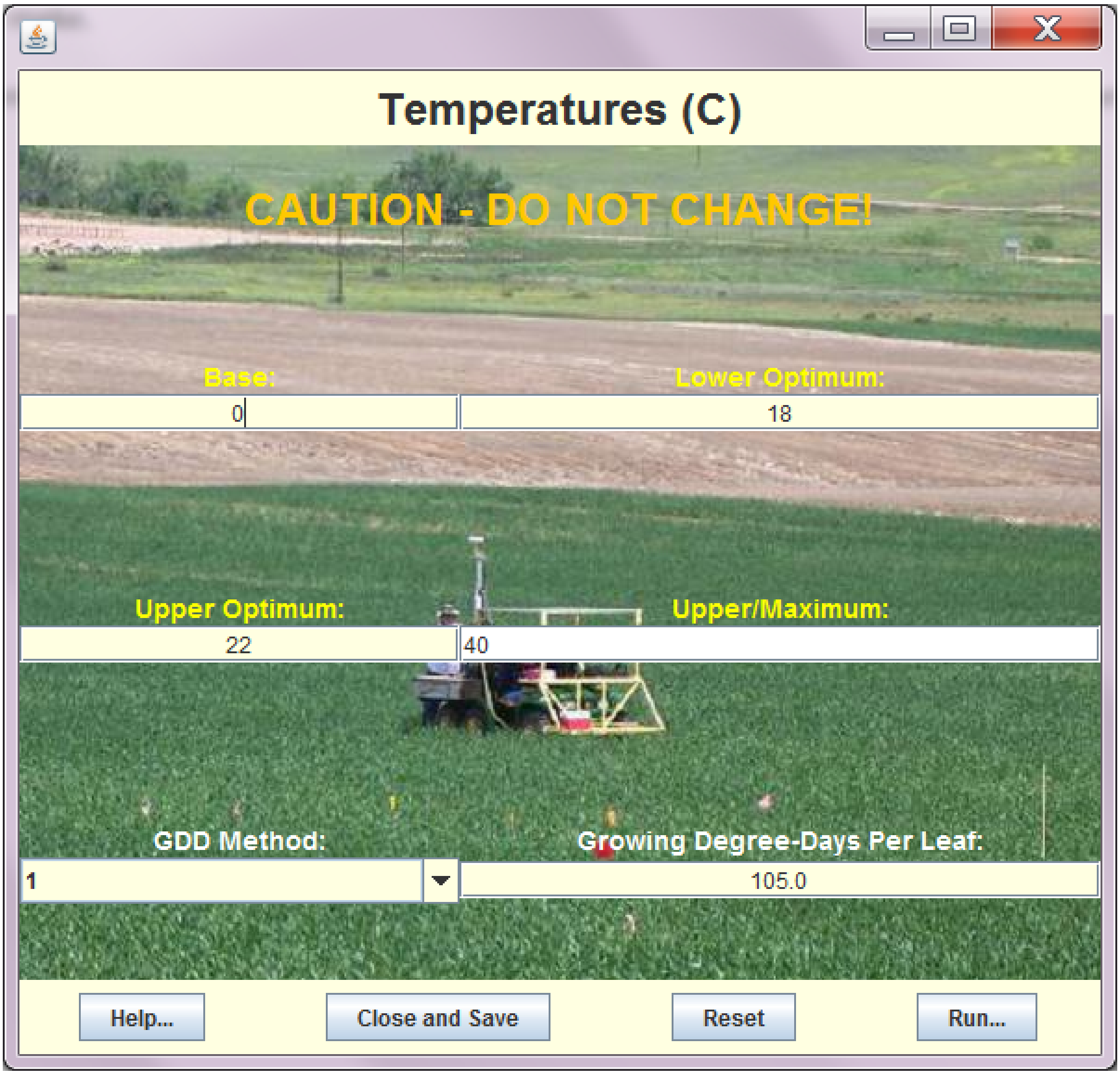


Links to: Temperatures

Temperatures

It is strongly recommended that the information in this screen not be changed as changing these values will negatively influence the program. They are presented here for information purposes only.

The 'Temperatures' screen presents important temperature and temperature-related input values.



Four temperature *inputs* are displayed that are used in calculating the *growing degree-days* (*GDD*) for each day as described in each *GDD method* below:

The *Base temperature* (*Tbase*) is the temperature below which no GDD are accumulated. The assumption is that phenological *development* does not occur below the base temperature, and therefore no GDD occur on that day. Tbase is used in all methods of calculating GDD (discussed below).

The *Lower Optimum temperature* (*Toptlo*) is the lower end of the optimum temperature range for *growth*. This is used only in Method 4 and currently is not implemented for any of the crops in *PhenologyMMS 1.3*.

The *Upper Optimum temperature* (*Toptup*) is the upper end of the optimum temperature range for growth. This is used only in Method 4 and currently is not implemented for any of the crops in PhenologyMMS 1.3.

The Upper/Maximum temperature (*Tupper*) is the highest temperature at which growth can still occur. This is used only in Methods 2, 3 and 4 but not implemented for any of the current crops in PhenologyMMS 1.3.

There are many ways that the GDD required between phenological stages can be calculated. Four commonly used methods are available in PhenologyMMS however, only two methods are currently implemented. Although these four methods are fairly similar, they have slight variations in approach and the temperature variables used.

WARNING: If you change the temperature values or the GDD Method in the Temperature screen, this will have an adverse effect on the simulation output as the parameter values in the Set Growth Stages screen which are based on the particular Method of calculating GDD for the crop, are NOT adjusted when temperatures or the GDD Method are changed.

The four GDD METHODS used are described below. For additional information, refer to: McMaster, G. S. 2009; McMaster, G. S. (2005); McMaster, G. S. and W. W. Wilhelm (1997); and McMaster, G. S., et al. (2013). A diagram of the four GDD Methods is displayed here.

GDD METHOD 1

This is probably the simplest method of the four. The Average (*Tavg*) of the Maximum temperature (*Tmax*) and the *Minimum temperature* (*Tmin*) is calculated. The Tbase is then subtracted from the Tavg. If the result is negative then the value is set equal to zero.

Method 1 is generally used for grasses and here it is applied to Winter Wheat, Spring Wheat, Winter Barley, Spring Barley, Proso Millet and Hay Millet.

GDD METHOD 2

This is another way of calculating GDD and uses the Upper Temperature (Tupper) threshold for the crop. GDD above the Tupper are not accumulated. Tbase is also used in this Method. Both Tmax and Tmin are compared to Tbase and if Tmax and/or Tmin is less than Tbase then Tmax and/or Tmin is set equal to the value of Tbase. Likewise, if Tmax and/or Tmin is greater than Tupper, then Tmax and/or Tmin is set equal to Tupper. The average temperature is calculated and Tbase is subtracted from Tavg. If the resulting value is less than zero, then it is set to zero.

Method Two is used for Corn, Sunflower, Sorghum and Dry Beans.

GDD METHOD 3

This method employs a two-segmented linear model. The first segment extends from Tbase to an Optimum Temperature (*Topt*), and the second segment extends from Topt to Tupper. The Average temperature is calculated and compared to Tbase and Topt. If Tavg is greater than or equal to Tbase and less than or equal to Topt, then a temperature factor '*tf*', which uses the slope of the first segment of the line, is calculated and multiplied by the value of Tavg minus Tbase. This gives the GDD value for the day. However, if the Tavg is greater than Topt and less than or equal to Tupper, then 'tf', which uses the slope of the second segment of the line, is multiplied by the value of Tavg minus Tbase to give today's GDD value. If neither comparisons are true and Tavg is less than Tbase or greater than Tupper, then the GDD for the day is zero.

GDD METHOD 4

This Method uses a three-segmented linear model. The first segment extends from Tbase to the Lower Optimum Temperature (Toptlo); the second segment from Toptlo to the Upper Optimum Temperature (Toptup); the third segment runs from Toptup to Tupper.

The Average temperature (Tavg) is calculated and compared to Tbase and the Lower Optimum Temperature (Toptlo). If Tavg is greater than or equal to Tbase and if Tavg is less than Toptlo, then Tbase is subtracted from Tavg. This value is multiplied by the calculated temperature factor 'tf' which is calculated using the slope of this first segment of the line to get the GDD value for the day. However, if Tavg is greater than or equal to Toptlo and less than or equal to Toptup, then Tbase is subtracted from Tavg and that value is multiplied by 'tf' which has been calculated using the slope of the second line segment. This gives the GDD value for the day. If Tavg is greater than Toptup and less than or equal to Tupper, then 'tf' is calculated using the slope of this third segment of the line and is multiplied by the result of Tavg minus Tbase to yield the GDD value for the day. If none of the situations are true and Tavg is less than Tbase or greater than Tupper, then GDD for the day is set equal to zero.

You can choose the GDD method with which to *run* the model however, only Methods 1 and 2 are currently implemented. The default is Method 1. Click on the down arrow to pick one of the other methods.

The *phyllochron* , or GDD per leaf, is also entered in this screen in the 'Growing Degree-Days per Leaf:' edit box. This refers to the number of GDD's required to produce an additional leaf.

The buttons below the picture are similar to those on the previous screens.

The 'Help…' button - accesses the Help System.

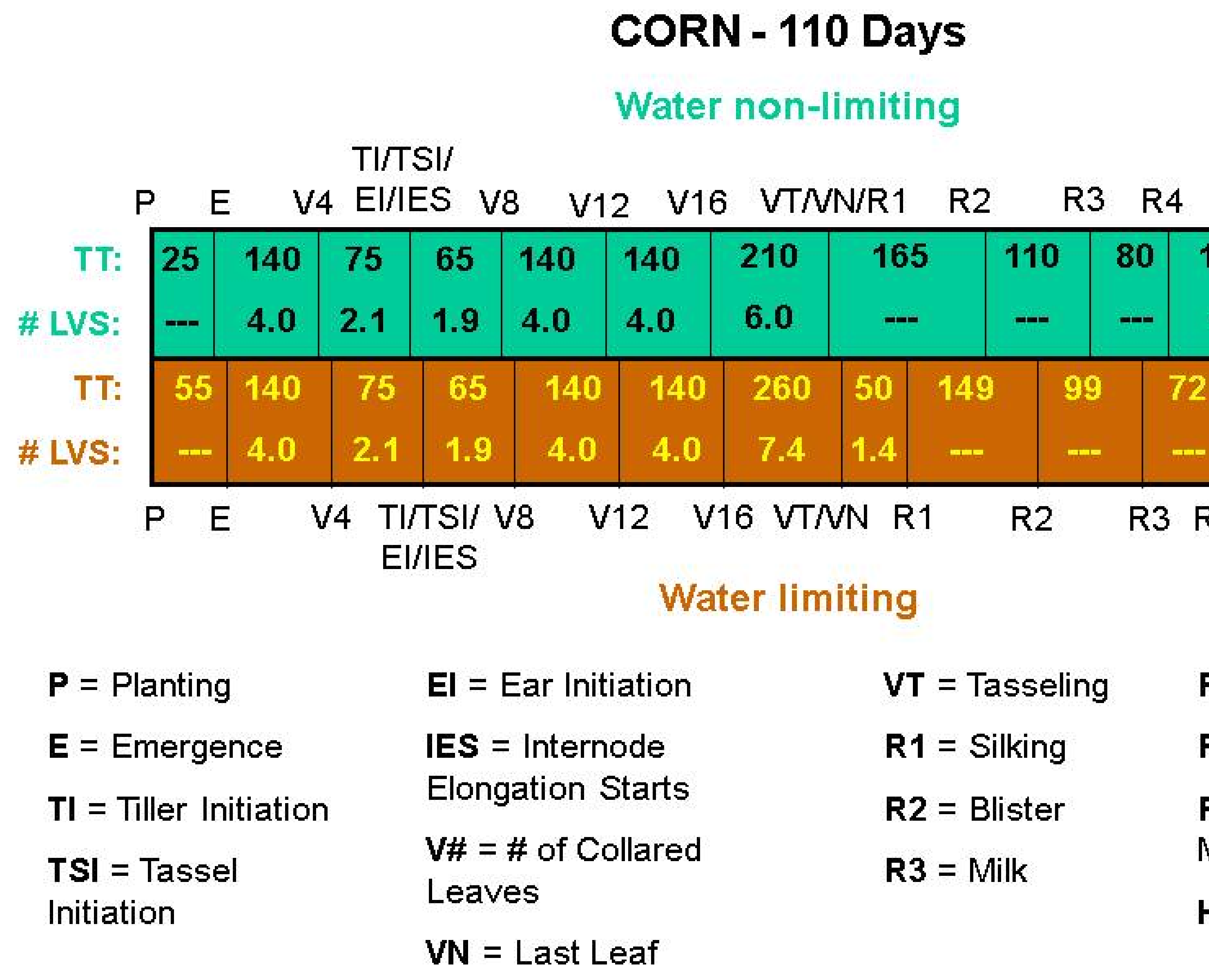
The 'Close and Save' button - closes this screen, returns you to the 'Set Inputs' screen and saves the information entered in the 'Temperatures' screen.

The 'Reset' button - resets the values back to the original default values.

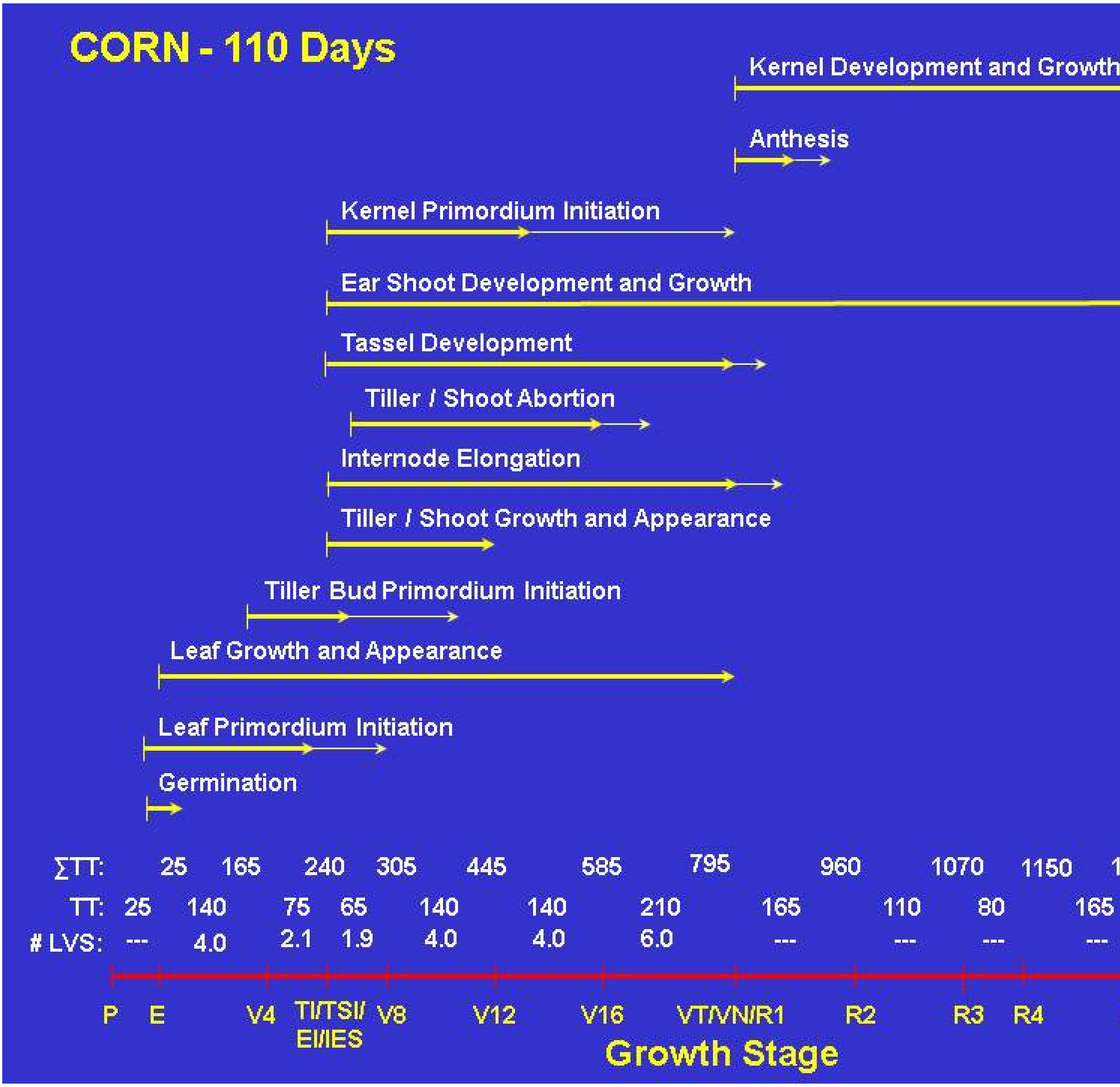
The 'Run…' button - runs the model and displays output in the Output screen.

Corn Diagrams

Phenology Diagram



Developmental Sequence



Links to: [Corn Growth Stages]()

Corn Growth Stages

The *Growth Stages* screen for Corn (*Zea mays* L.) is displayed below. Please see the Growth Stages Example topic for a general description of the growth stages screen.

Fourteen different growth stages are given for a corn plant. A plant is determined to be at a specific growth stage when 50% of the plants in the field have reached the stage under consideration. They are listed here and include:

Seeding (S) to *Emergence* (E) – the *seedling* emerges from the soil.

Vegetative growth:

E to 4th Leaf (V4) – emergence of the seedling has occurred and four *leaves* are present each with a visible leaf *collar*. This is one of the vegetative stages.

V4 to *Tassel* Initiation – the vegetative stage continues to when tassels are initiated.

V4 to *Ear* Initiation – the vegetative stage continues to when ears are initiated. *Ear Initiation*, *tassel initiation*, *tiller* initiation and *internode elongation* all occur at approximately the same time.

V4 to Internode Elongation Begins – the vegetative stage continues to when the internodes between leaves begin to elongate. That is, the *stem* begins to elongate. This also, occurs at about the same time as the two previous stages plus *tiller initiation*.

V4 to 12th Leaf (V12) – vegetative growth continues resulting in 12 leaves with visible leaf collars. This too, occurs at approximately the same time as the three previous stages plus tiller initiation.

V12 to *Tasseling* – tassels are visible at this stage.

Grain filling:
The following reference was very helpful in describing the reproductive stages: 'R. L. ‘Bob’ Nielsen. Updated August, 2013. [Grain fill stages in corn](http://www.kingcorn.org/news/timeless/GrainFill.html). URL: http://www.kingcorn.org/news/timeless/GrainFill.html Purdue University, West Lafayette, IN.'.

V12 to *Silking* (R1) – this occurs at about the same time as tasseling and indicates a shift in the plant from vegetative growth to reproductive stages. The *silks* are the functional *stigma* of the *female flower* and develop from the ovules. *Pollen* grains are released by the male flowers and when captured by the silks, germinate and develop pollen tubes that penetrate the silk tissue. The germinated pollen grains or male gametes travel down the *pollen tube* and fertilize the *ovule*. The ovules closest to the base of the ear develop silks first and silking proceeds up the ear to the tip.

R1 to *Blister* (R2) – this is the second reproductive stage and the *kernels* appear as whitish blisters on the cob. They contain much clear fluid and some starch.

R2 to *Milk* (R3) – by this stage the kernels contain a milky white fluid and the kernels are mostly yellow. Starch continues to accumulate.

R3 to *Dough* (R4) – the kernel’s fluid is a *soft dough* due to starch accumulation which continues in this stage. The kernels now have about 50% of their mature dry weight.

R4 to *Dent* (R5) – the kernels show a dent in the *crown*. There is also a *milk line* which is the boundary between the milk and starch layers. The milk line is near the dent end of the kernel and progresses to the tip end of the kernel over approximately three weeks.

R5 to *Maturity* R6) – at this stage the kernels are at their maximum dry weight and are considered to be physiologically mature. This occurs just after the milk line disappears and just before the *black layer* forms at the tip of the kernel.

R6 to *Harvest Ready* – the kernels are ready for harvest when their moisture content has decreased to near 25%. Minimal damage will occur during harvest.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Corn hybrids which are divided based on Days in which they are expected to reach maturity given normal growing conditions. The hybrids here range from 90-Day to 120 Day. The *Generic hybrid* is considered to be the same as the 110-Day hybrid.

The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to the Phenology Diagram and the Developmental Sequence for Corn.

Dry Beans Diagrams

Phenology Diagram

DRY BEAN

Water non-limiting

S E VC V1 V2 V3 V4 R1 R2 R3 R4 R5

TT:	30	20	15	25	40	30	270	75	50	75	115
# LVS:	---	0.6	0.5	0.8	1.3	0.9	8.4	2.3	1.6	2.3	3.6

TT:	50	25	30	50	50	85	200	105	55	135	90	7
# LVS:	---	0.8	0.9	1.6	1.6	2.7	6.3	3.3	1.7	4.2	2.8	2

S E VC V1 V2 V3 V4 R1 R2 R3 R4 R5

Water limiting

S = Sowing

E = Emergence

VC = Cotyledonary Lvs

V1 = 1st Trifoliolate Lf

V2 = 2nd Trifoliolate Lf

V3 = 3rd Trifoliolate Lf

V4 = 4th Trifoliolate Lf

R1 = Bloom

R2 = Mid-full Flower

R3 = Early Pod Set

R4 = Mid Pod Set

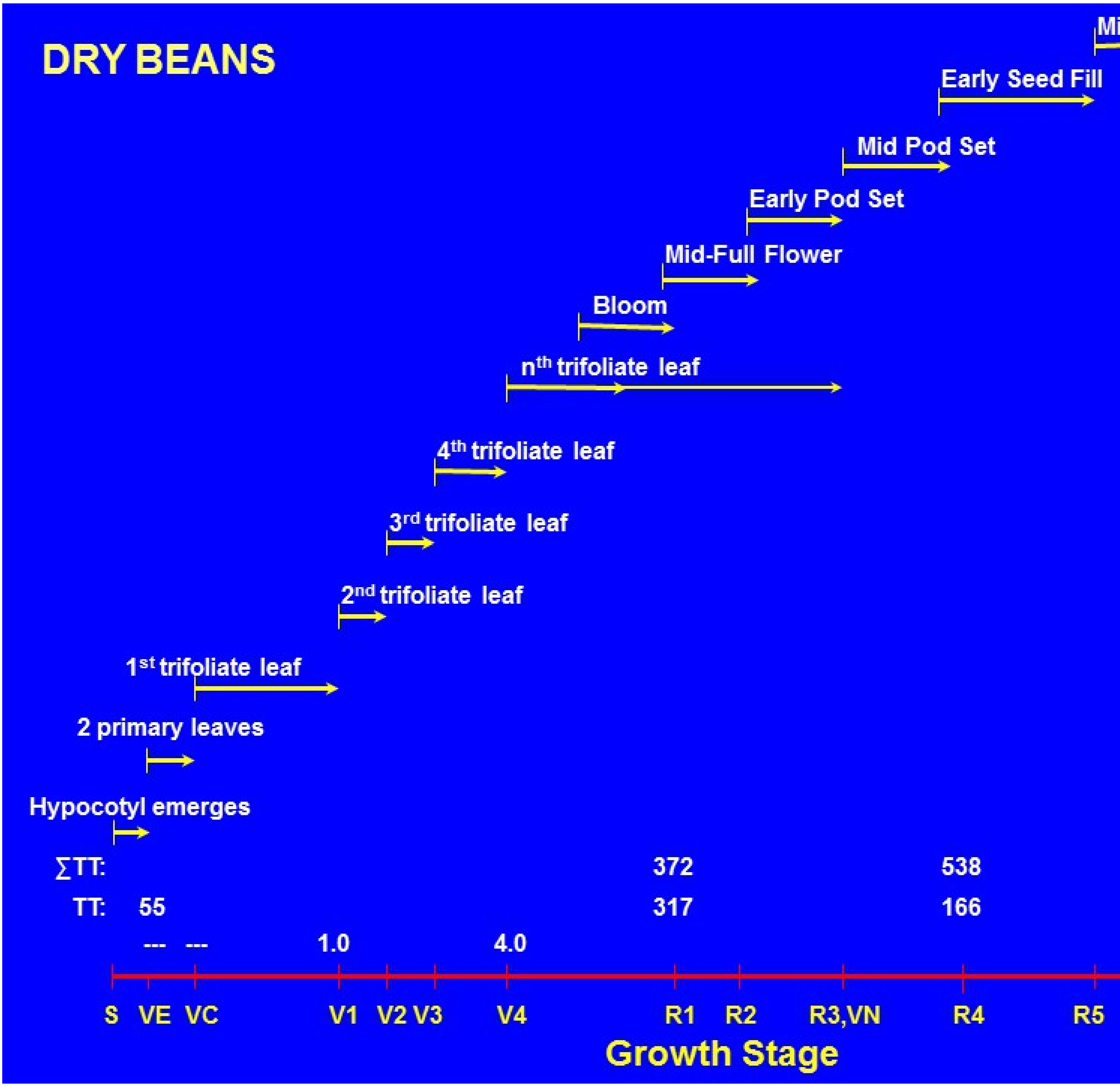
F

F

F

H

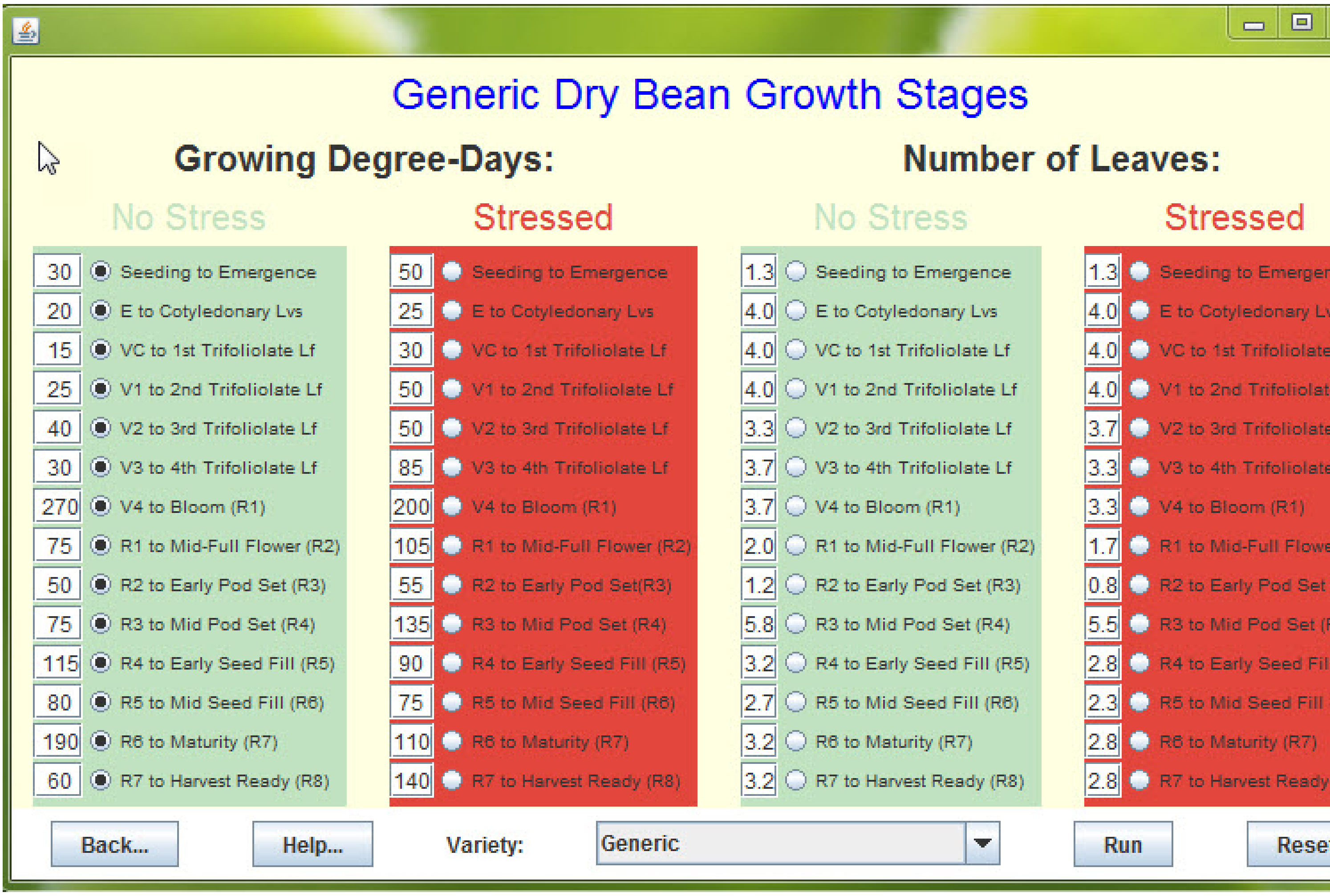
Developmental Sequence



Links to: [Dry Beans Growth Stages]()

Dry Bean Growth Stages

The *Growth Stages* screen for Dry Beans (*Phaseolus vulgaris* L.) is displayed below showing the parameters for the *Generic* variety. Please see the [Growth Stages Example] topic for a general description of the growth stages screen.



There are fourteen growth stages for dry beans. According to the "[Dry Bean Production & Pest Management Bulletin 562A]", there are four developmental stages in Dry Beans. Stage I is the first part of the *vegetative phase* and includes *germination* , *emergence* and the early part of vegetative growth. Stage II occurs in the latter half of the vegetative phase from the emergence of the third *trifoliate leaf* to the first flower opening. Stage III is in the first part of the *reproductive phase* of the life cycle. While in Stage III, the plant progresses from the first flower to mid *pod* set. The last stage, Stage IV completes the reproductive phase of plant growth and occurs from the beginning of filling of the first-formed pods to *maturity* and ready for harvest.

Vegetative:
Seeding to Emergence E) - the *seedling* emerges through the soil and the *hypocotyl* appears.
E to *Cotyledonary Leaves* (*VC*) - there are two cotyledons above ground at the first *node* and two

primary, unifoliate *leaves* are unfolded at node 2.
VC to 1st Trifoliate Leaf (V1) - the first trifoliate leaf has unfolded at node 3.
V1 to 2nd Trifoliate Leaf (V2) - the second trifoliate leaf has unfolded at node 4.
V2 to 3rd Trifoliate Leaf (V3) - the third trifoliate leaf has unfolded at node 5.
V3 to 4th Trifoliate Leaf (V4) - the fourth trifoliate leaf has unfolded at node 6. Branches develop and vegetative growth progresses rapidly.

Reproductive:
V4 to *Bloom* (R1) - there is one open flower.
R1 to *Mid-Full Flower* (R2) - 50% of the flowers are open.
R2 to *Early Pod Set* (R3/*VN*) - one pod has reached maximum length. The Early *Pod Set* R3 stage is also the VN stage when the last trifoliate leaf is produced. Leaves continue to be added until the R3/VN stage.
R3 to *Mid Pod Set* (R4) - 50% of the pods are at maximum length.
R4 to *Early Seed Fill* (R5) - one pod has fully developed seeds.
R5 to *Mid Seed Fill* (R6) - 50% of the pods contain fully developed seeds.
R6 to Maturity (R7) - one pod has changed color to a mature color such as yellow, tan, purple or even striped. This indicates *physiological maturity*.
R7 to *Harvest Ready* (R8) - the plant is ready to be harvested; 80% of the pods have changed to the mature color.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Dry Bean types and varieties. Two types of dry beans based on growth habit are included and they are *Bush* or *Vine* types. There are four selections based on time to Maturity and include *Early Maturity* (E, 85-95 days), *Medium Maturity* (also Generic in this listing) (M, 90-94 days), *Full Season* (F, 95-99 days) and *Late Maturity* (L, 100 or more days). Quite a few varieties are listed with these Maturity designations and an additional one relating to growth habit. The growth habits include: V (vine), SU (semi-upright), U (upright) and B (Bush).

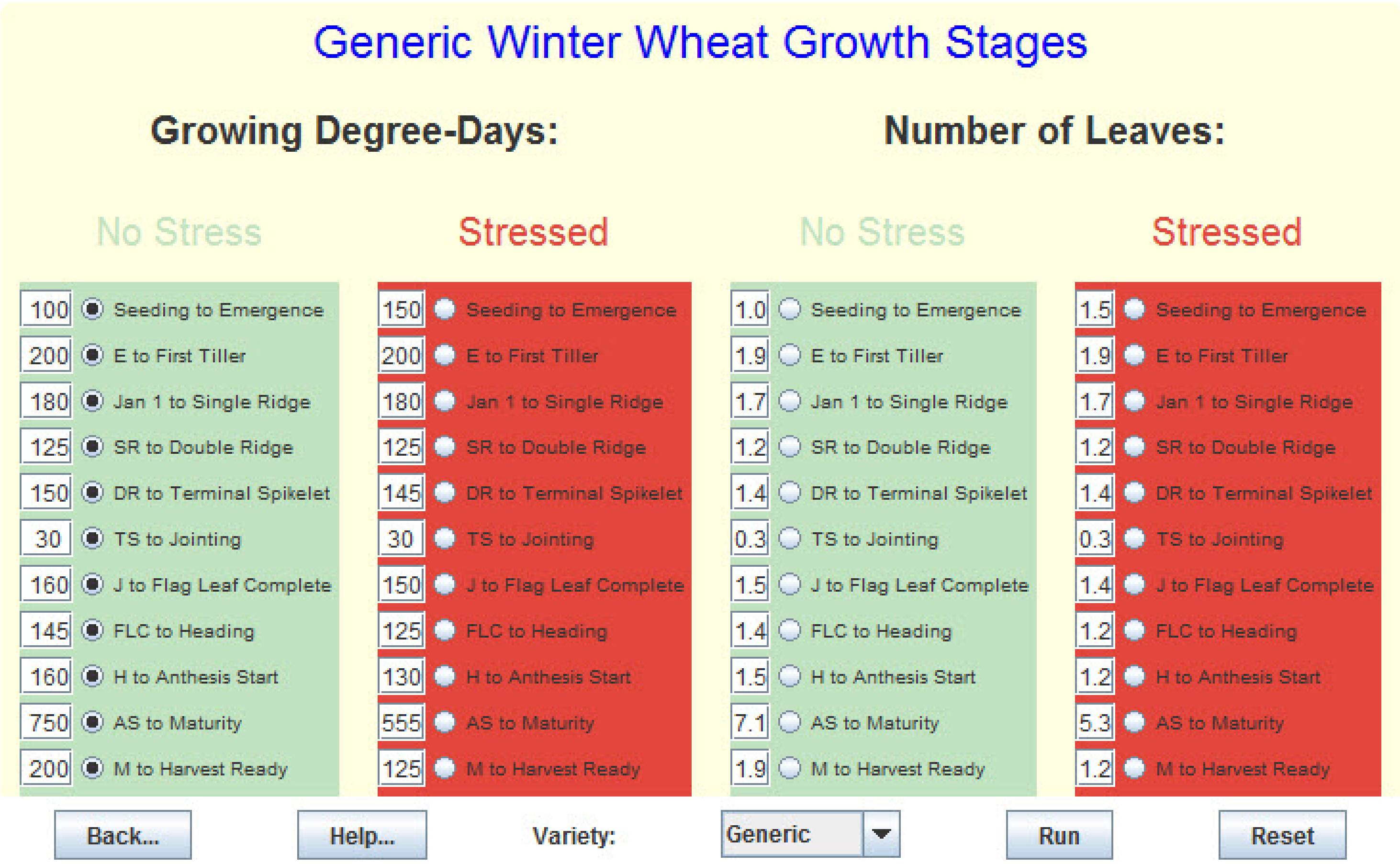
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to the Phenology Diagram and the Developmental Sequence for Dry Beans.

Growth Stages Example

The *Growth Stages* screen in PhenologyMMS is designed specifically for each crop. It contains the appropriate growth stages for the crop and provides two ways to determine which growth stage the plant is in. The image below displays the Generic variety of [Winter Wheat].



The left hand side of the screen contains parameters for each stage using Growing Degree Days (*GDD*), i.e., *thermal time*, in a non-stressed environment comparable to an irrigated field and a stressed environment analogous to a dryland or rainfed operation.

The two columns on the right hand side of the screen show the number of *leaves* added at each growth stage based on the *phyllochron* entered for the crop on the Temperatures screen in the ["Growing Degree-Days per Leaf"] edit box, again under non-stressed and stressed conditions. These values are editable.

If the user has a better estimate of the number of GDD for a stage or stages in any of the four columns, they may enter that value for the appropriate stage. Rarely, is a crop completely stressed or completely non-stressed so an intermediate value may be a better choice in either the stressed or the non-stressed column - whichever one the user feels the crop is closest to under current conditions. A combination of selections can be used. For example, a user might select some number of growth stage values in the non-stressed column while the plant/crop is not stressed and then select growth stage values in the stressed column when the plant/crop is likely to encounter stressful growing conditions. The same applies to the *Number of Leaves* columns if the user is using this method to determine when a growth stage is reached. It is possible to use any combination of all four columns.

The other selection the user will want to make is the Variety. Different crops have differing numbers of varieties available in the Variety drop-down box. Sometimes there are only four which include Early Maturing, Medium Maturing, Late Maturing and *Generic*. The Generic variety is the same as the Medium Maturing variety.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down box lists one or more varieties for the crop displayed. At the least, there are always four varieties: Generic, *Early Maturity*, *Medium Maturity* and *Late Maturity*. The Medium Maturity variety is equal to the Generic variety. Corn is the exception to this standard. Corn is presented in terms of 'Days', e.g., '110 Day', which indicates the approximate days to maturity. For some crops, additional named varieties or plant type varieties are given. Dry Beans adds two varieties based on growth type, i.e., *Bush* and *Vine*. Spring Barley and Spring Wheat add additional varieties based on the total number of leaves expected, e.g., '8-leaved;. Sunflower adds two varieties for the *Oil* and *Seed* (confectionery) types of sunflower.

The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to: GDD Methods
Temperatures
Winter Wheat Growth Stages

Hay Millet Diagrams

Phenology Diagram

HAY MILLET

Water non-limiting

S E TI SR DR IE/ESI J FLC/B H A

TT:	150	170	30	150	150	150	200	500	150	700
# LVS:	---	1.6	0.3	1.4	1.4	1.4	1.9	4.8	1.4	6.7

TT:	150	170	30	150	150	150	225	600	175	550
# LVS:	---	1.6	0.3	1.4	1.4	1.4	2.1	5.7	1.7	5.2

S E TI SR DR IE/ESI J FLC/B H A

Water limiting

S = Sowing

E = Emergence

TI = Tiller Initiation

SR = Single Ridge

DR = Double Ridge

IE = Internode Elongation

ESI = End of Spikelet Initiation

J = Jointing

FLC = Flag Leaf Complete

B = Booting

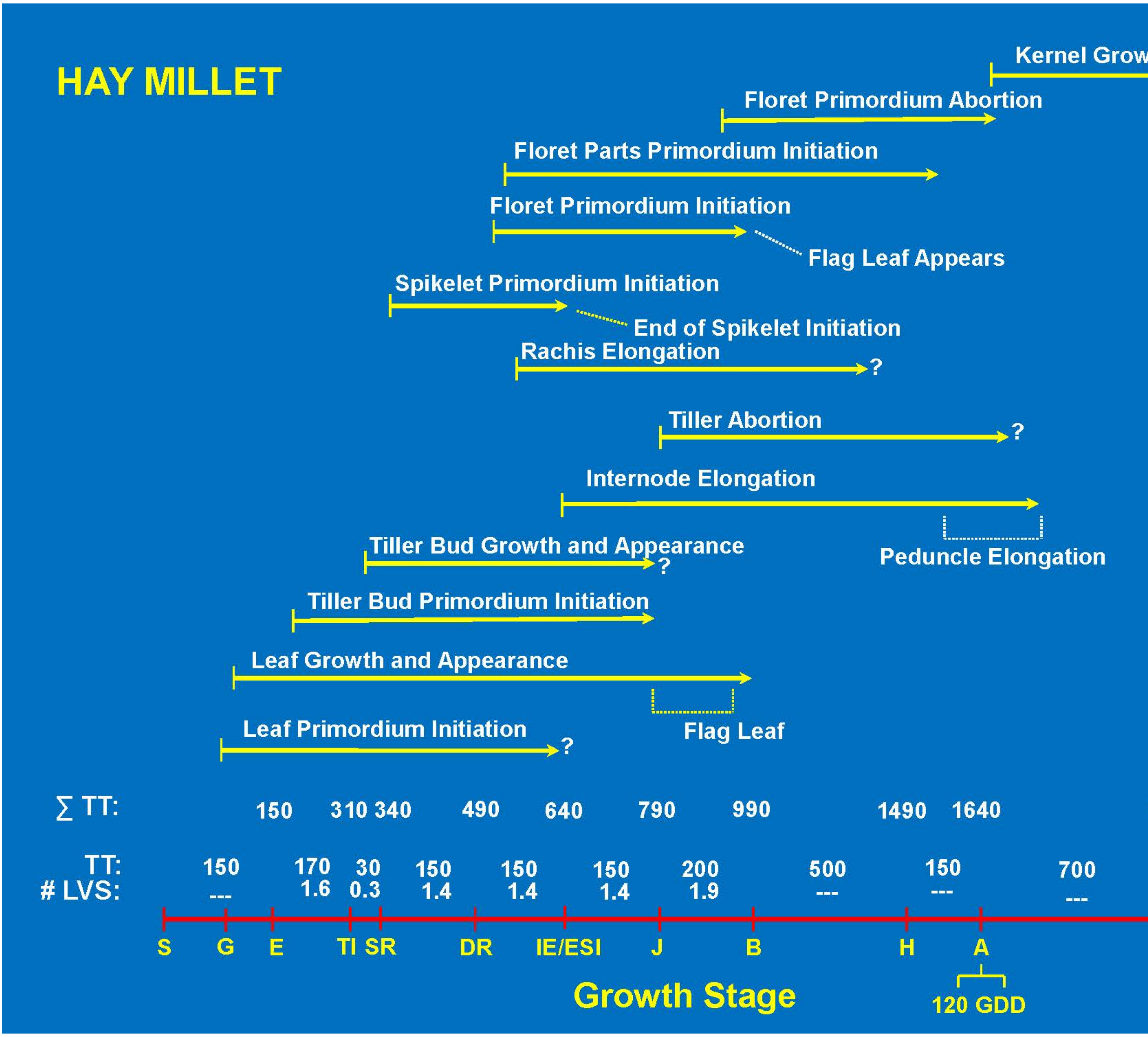
H = Heading

A = Anthe

M = Phys Ma

HR = Har

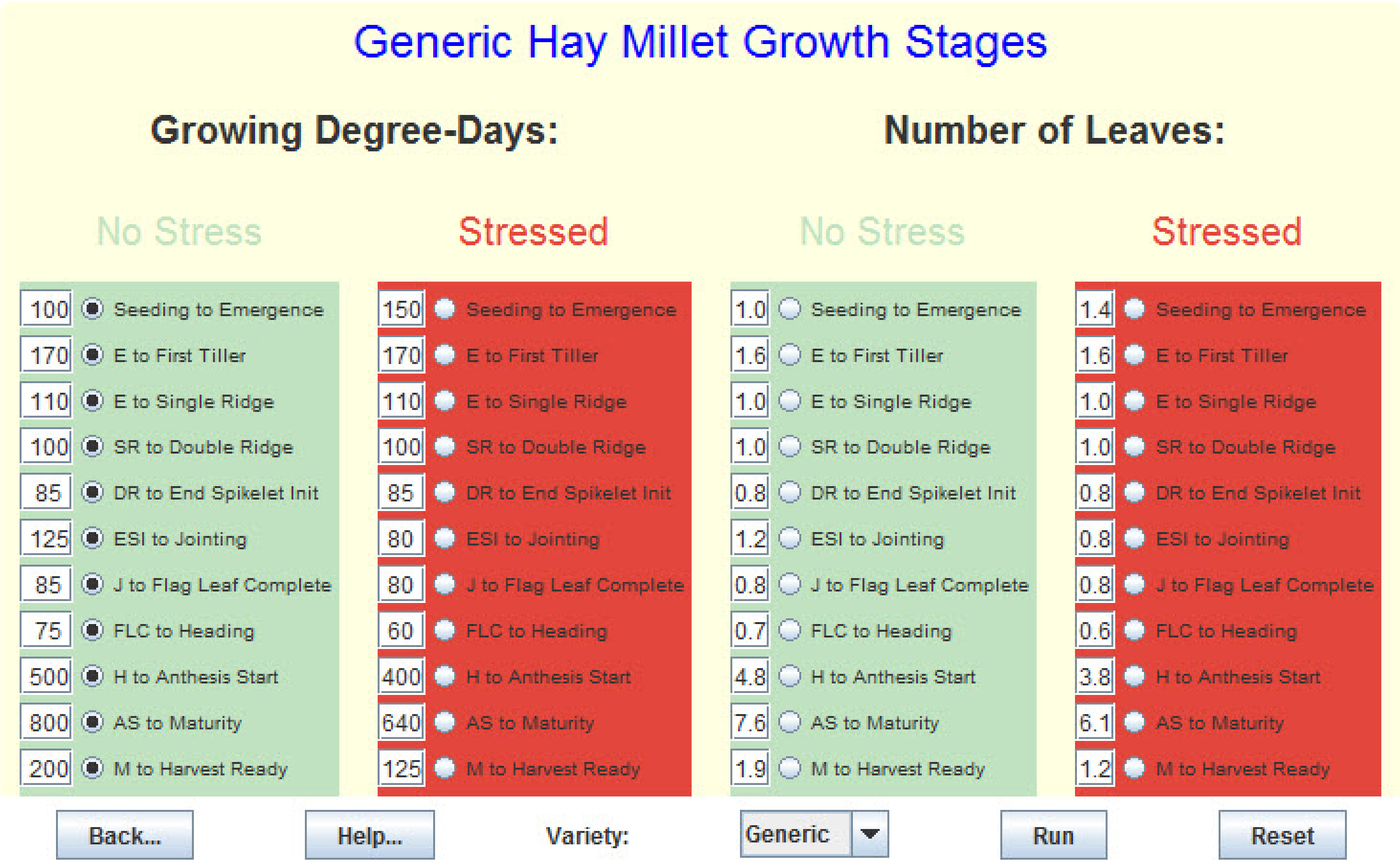
Developmental Sequence



Links to: [Hay Millet Growth Stages]()

Hay Millet Growth Stages

The Hay Millet *Growth Stages* screen is displayed below showing the parameters for the Generic Variety. Hay Millet is also known as *Foxtail Millet* (*Setaria italica* (L.) P. Beauv.) . Please see the [Growth Stages Example]() topic for a general description of the growth stages screen.



Hay Millet has eleven growth stages which follow those of winter wheat with small differences. A description of each stage follows.

Seeding to *Emergence* (E) - *germination* occurs and the young *seedling* pushes through the soil to the soil surface.

E to First *Tiller* - the first tiller emerges.

E to *Single Ridge* (*SR*) - single ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to *Double Ridge* (*DR*) - the tissue between the single ridges develop into *spikelet primordium* resulting in the double ridge stage.

DR to *End Spikelet Initiation* (*ESI*) - spikelet primordium continue to be initiated until the end of spikelet initiation.

ESI to *Jointing* (J) - jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot. The developing *head* can be seen inside the *stem* if the stem is cut open.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the head and this is referred to as *booting* or Flag Leaf Complete.

FLC to *Heading* (H) - when the hay millet head is visible in the leaf *sheath* of the flag leaf, *booting* has occurred. When the head emerges from the leaf sheath, heading has occurred.

H to *Anthesis Starts* (*AS*) - the head is beginning to flower. *Anthers* are visible at this stage and *pollination* is occurring.

AS to *Maturity* (M) - pollination progresses until complete and the *kernels* ripen and progress from being *watery ripe* to *milky ripe* to *dough* to hardening.

M to *Harvest Ready* - the kernels are sufficiently hard and at the proper moisture content so harvest can commence.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Hay Millet varieties in a general sense based on time to maturity. There are four varieties and include *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*.

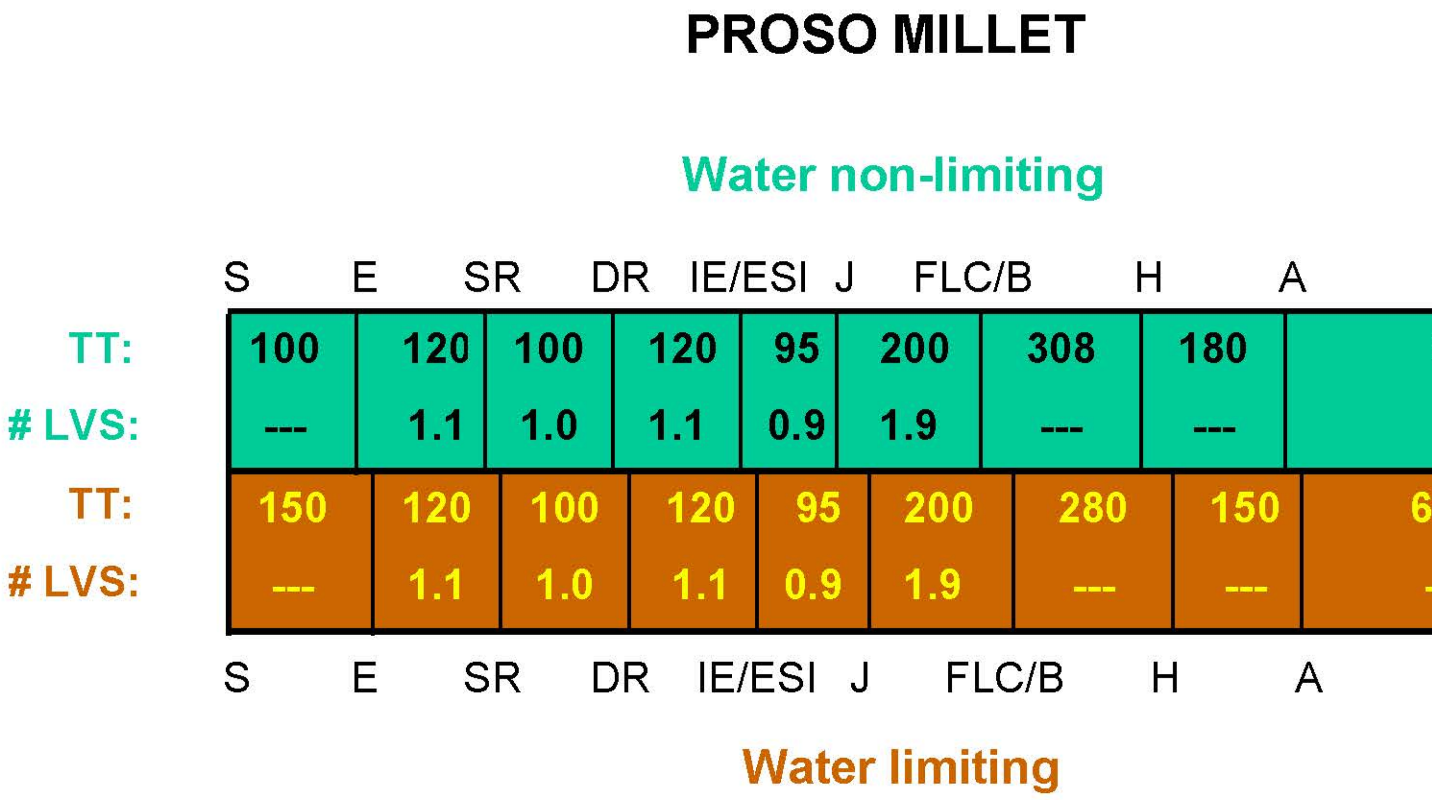
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to the Phenology Diagram and the Developmental Sequence for Hay Millet.

Proso Millet Diagrams

Phenology Diagram



S = Sowing

E = Emergence

TI = Tiller Initiation

SR = Single Ridge

DR = Double Ridge

IE = Internode Elongation

ESI = End of Spikelet Initiation

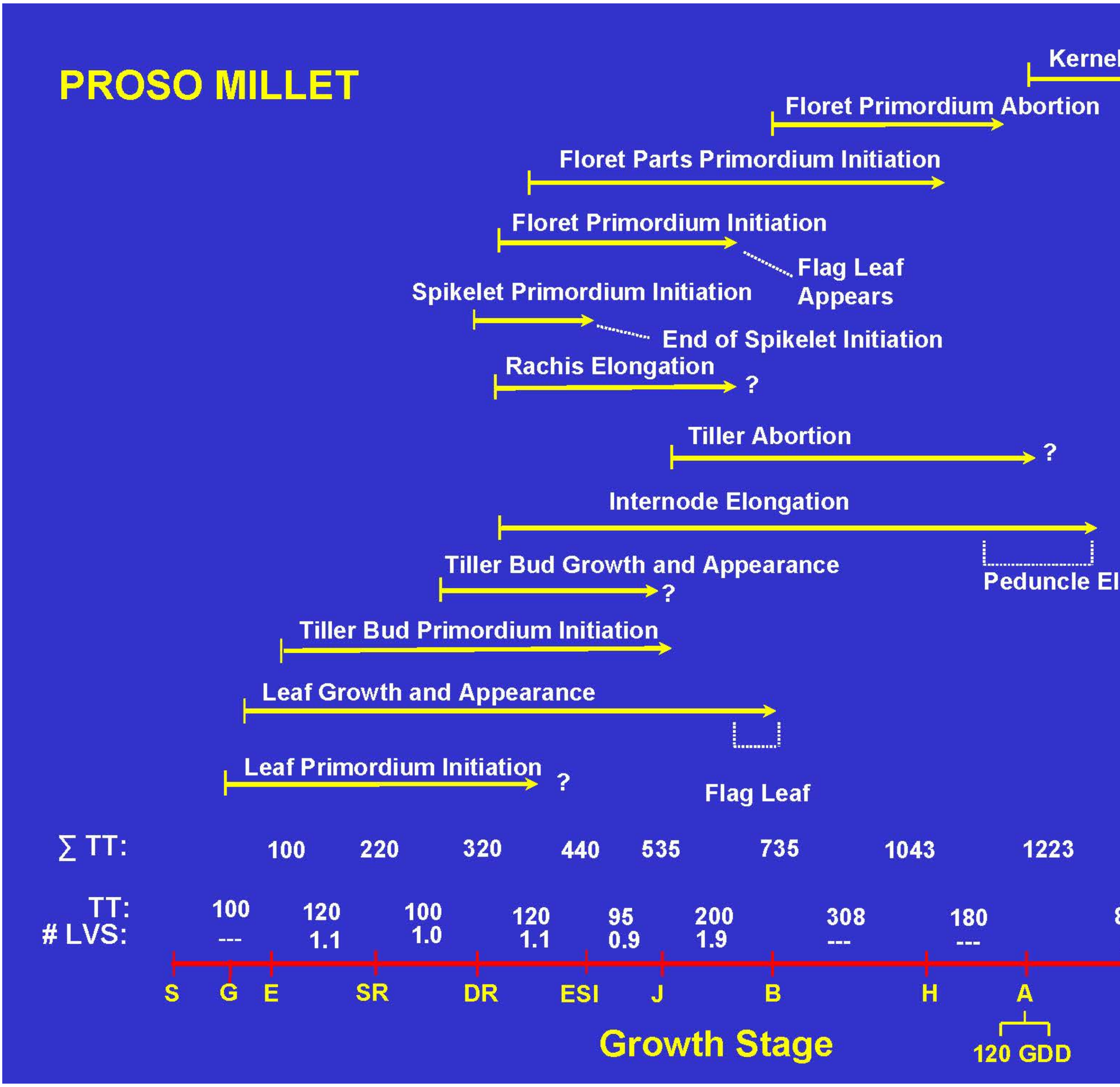
J = Jointing

FLC = Flag Leaf Complete

B = Booting

H = Heading

Developmental Sequence



PROSO MILLET
Kernel
Floret Primordium Abortion
Floret Parts Primordium Initiation
Floret Primordium Initiation
Flag Leaf Appears
Spikelet Primordium Initiation
End of Spikelet Initiation
Rachis Elongation
?
Tiller Abortion
?
Internode Elongation
Peduncle El
Tiller Bud Growth and Appearance
?
Tiller Bud Primordium Initiation
Leaf Growth and Appearance
Leaf Primordium Initiation
?
Flag Leaf
∑ TT: 100 220 320 440 535 735 1043 1223
TT: 100 120 100 120 95 200 308 180
LVS: --- 1.1 1.0 1.1 0.9 1.9 --- ---
S G E SR DR ESI J B H A
Growth Stage
120 GDD

Proso Millet Growth Stages

The Proso Millet (*Panicum miliaceum* L.) *Growth Stages* screen is displayed below showing the parameters for the Generic Variety. Please see the [Growth Stages Example]() topic for a general description of the growth stages screen.

Proso Millet has eleven growth stages which follow those of winter wheat with small differences. A description of each stage follows.

Seeding to *Emergence* (E) - *germination* occurs and the young *seedling* pushes through the soil to the soil surface.

E to First *Tiller* - the first tiller emerges.

E to *Single Ridge* (*SR*) - single ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to *Double Ridge* (*DR*) - the tissue between the single ridges develop into *spikelet primordium* resulting in the double ridge stage.

DR to *End Spikelet Initiation* (*ESI*) - spikelet primordium continue to be initiated until the end of spikelet initiation.

ESI to *Jointing* (J) - jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot. The developing *head* can be seen inside the *stem* if the stem is cut open.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the head and this is referred to as *booting* or Flag Leaf Complete.

FLC to Heading (H) - the head is visible in the *sheath* of the flag leaf and *booting* has occurred. When the head emerges from the leaf sheath, heading has occurred.

H to *Anthesis Starts* (*AS*) - the head is beginning to flower. *Anthers* are visible at this stage and *pollination* is occurring.

AS to *Maturity* (M) - pollination progresses until it is complete and the *kernels* ripen and progress from being *watery ripe* to *milky ripe* to *dough* to hardening.

M to *Harvest Ready* - the kernels are sufficiently hard and at the proper moisture content and harvest can commence.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Proso Millet varieties in a general sense based on time to maturity. There are four varieties and include *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*.

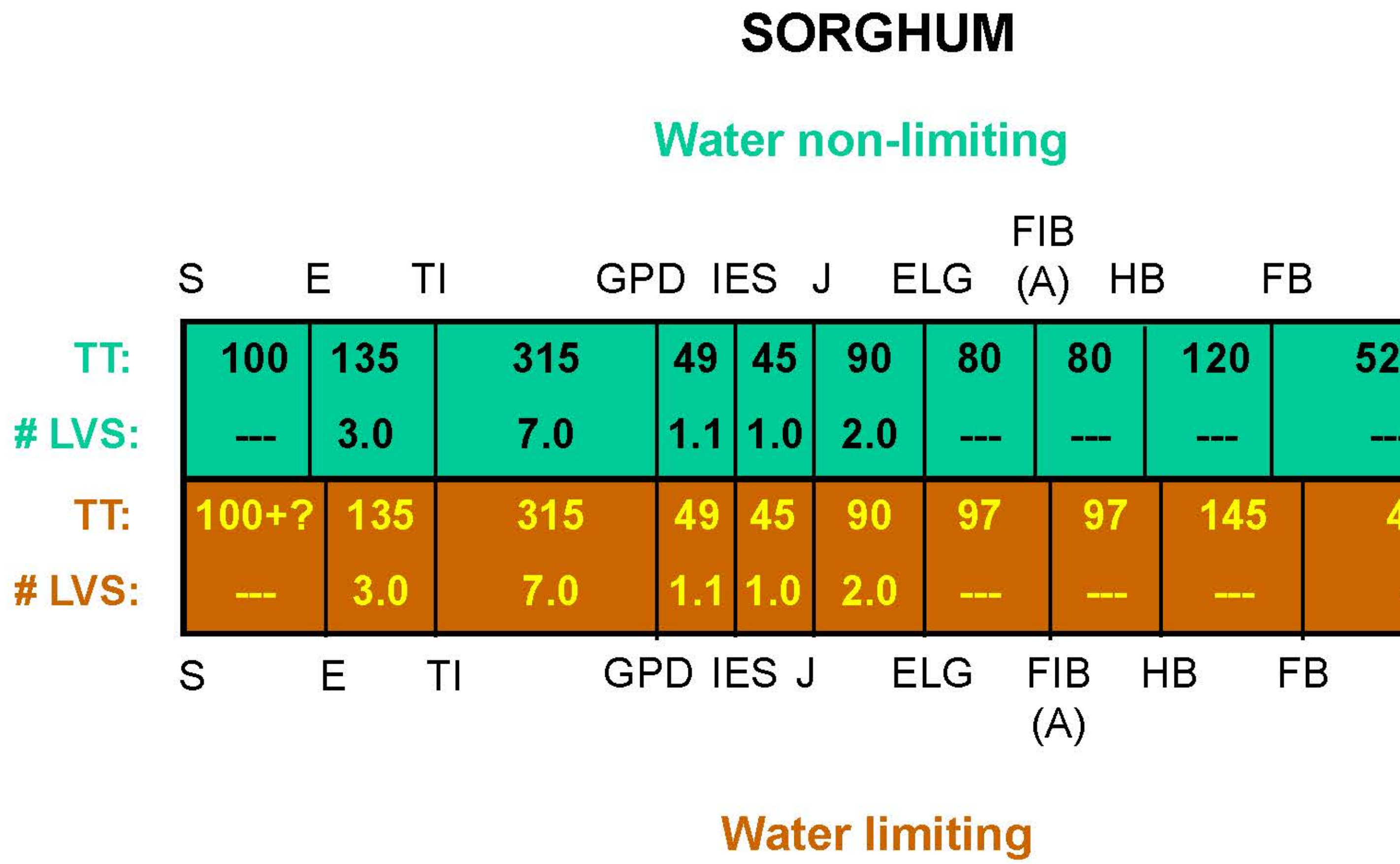
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to the Phenology Diagram and the Developmental Sequence for Proso Millet.

Sorghum Diagrams

Phenology Diagram



S = Sowing

E = Emergence

TI = Tiller Initiation

GPD = Growing Point Differentiation

IES = Internode Elongation Starts

J = Jointing

ELG = End of Leaf Growth

FIB = First Bloom (Anthesis Starts)

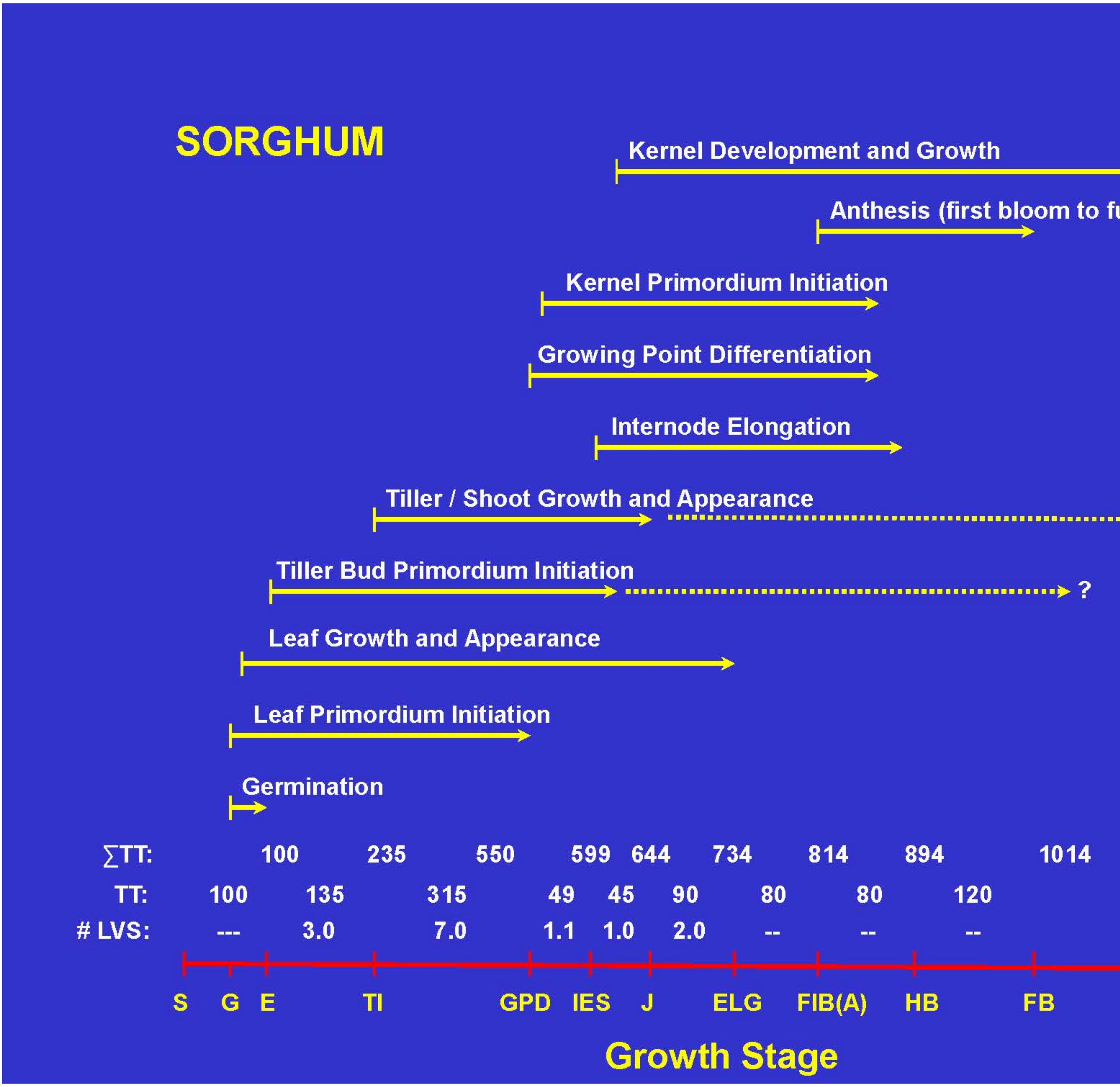
HB = Half Bloom

F

M

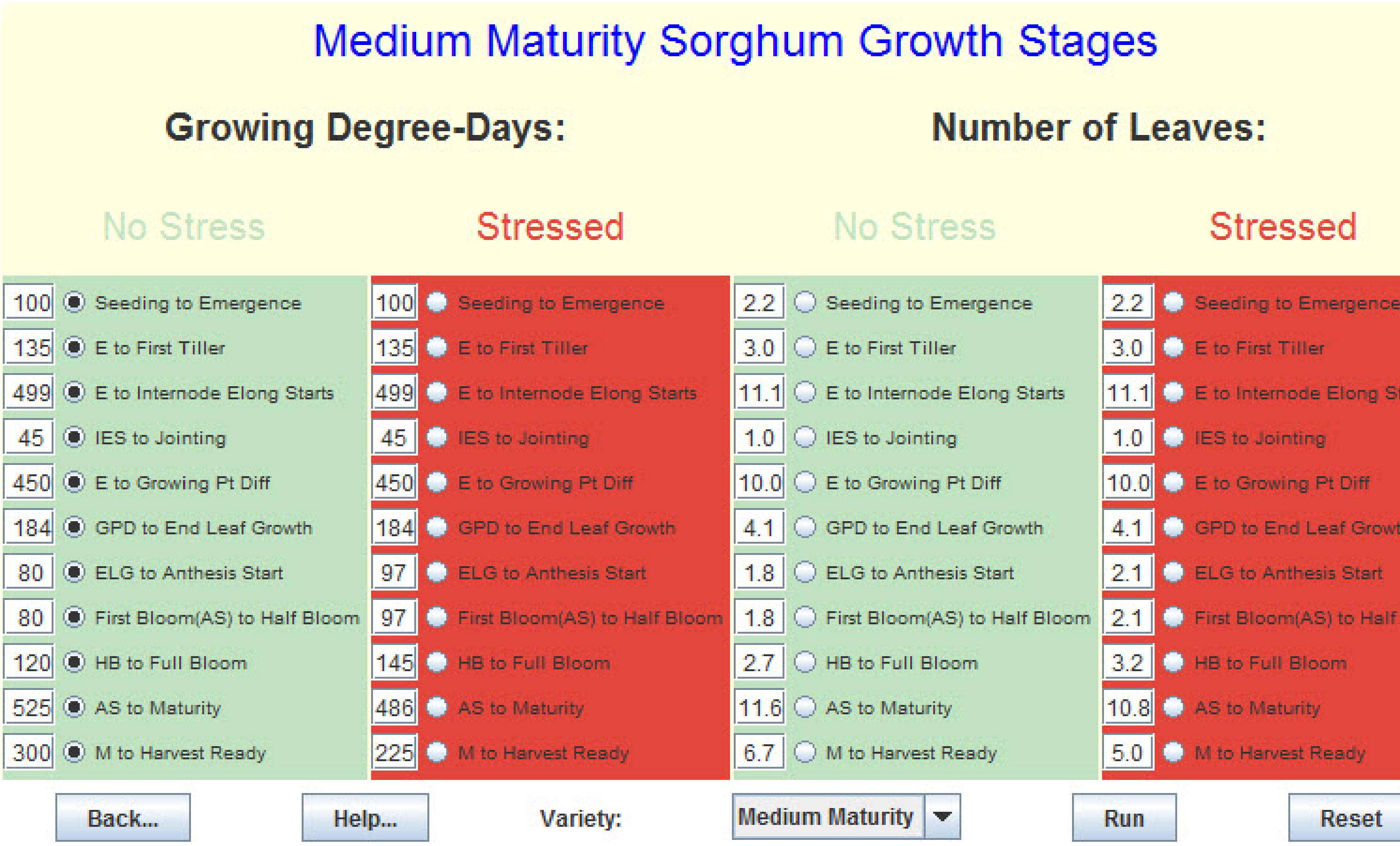
H

Developmental Sequence


SORGHUM
Kernel Development and Growth
Anthesis (first bloom to fu
Kernel Primordium Initiation
Growing Point Differentiation
Internode Elongation
Tiller / Shoot Growth and Appearance
Tiller Bud Primordium Initiation
?
Leaf Growth and Appearance
Leaf Primordium Initiation
Germination
∑TT: 100 235 550 599 644 734 814 894 1014
TT: 100 135 315 49 45 90 80 80 120
LVS: --- 3.0 7.0 1.1 1.0 2.0 -- -- --
S G E TI GPD IES J ELG FIB(A) HB FB
Growth Stage

Sorghum Growth Stages

The Sorghum (*Sorghum bicolor* (L.) Moench) *Growth Stages* screen displayed below shows the parameters for the Medium variety which is analogous to the Generic variety. Please see the [Growth Stages Example](#) topic for a general description of the growth stages screen.



Sorghum has eleven growth stages depicted in PhenologyMMS which follow those of winter wheat with a few differences.

A more generalized view of sorghum divides its growth into three stages. The first stage (*GS I*) is when vegetative growth occurs, the second stage (*GS II*) is when the reproductive structures are formed and the third stage (*GS III*) is devoted to grain *ripening*.

A description of the stages in PhenologyMMS follows:

Seeding to *Emergence* (E) - *germination* occurs and the young *seedling* pushes through to the soil surface making the *coleoptile* visible.

E to First *Tiller* - the first tiller emerges and occurs at the four and six-leaf stage.

E to *Internode Elongation Starts* (*IES*) - the internode begins to elongate.

IES to *Jointing* (J) - jointing occurs when the first *node* is present. However, this is not externally visible in sorghum.

E to *Growing Point Differentiation* (*GPD*) - the growing point differentiates or changes from producing *leaves* to producing reproductive structures, i.e., the *head*.

GPD to *End of Leaf Growth* (*ELG*) - the end of leaf growth occurs when the *flag leaf* has emerged from the *whorl*, the *collar* of the flag leaf is visible and all leaves are fully expanded. The head is nearly full size and is enclosed in the *sheath* of the flag leaf. The plant is now in the boot stage.

ELG to *Anthesis Starts* (*AS*) - the *peduncle* pushes the *panicle* from the flag leaf sheath. Heading has occurred when 50% of the plants have a visible panicle. *Flowering* or anthesis starts or *first bloom* starts from the tip of the head and progresses down the panicle.

First *Bloom* AS to *Half Bloom* (*HB*) - the head is considered to be at half bloom when flowering has progressed halfway down the panicle; the field is at half-bloom when 50% of the plants in the field are at some stage of bloom.

HB to *Full Bloom* (*FB*) - the heads of the plants are fully bloomed.

AS to *Maturity* (M) - this stage covers the beginning of flowering through the *development* of the *kernels* into mature grain. This encompasses the *milk*, *soft dough* and *hard dough* stages of the kernel. The grain is physiologically mature when the *black layer* appears above the point where the kernel was attached in the *florets* near the kernel base.

M to *Harvest Ready* - the kernel needs to dry down before reaching harvest ready. When the moisture content is 20%, the grain can be harvested but it is better to dry to 14% to safely store the grain in bins when drying equipment is not available.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Sorghum varieties in a general sense based on time to maturity. There are four varieties and include *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*.

The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

Links to the Phenology Diagram and the Developmental Sequence for Sorghum.

Soybean Diagrams

Phenology Diagram

SOYBEAN

Water non-limiting

P VE VC GPD/V1/IE V2 V3 V4 V5 R1 R2 R3 R

TT:	89	69	78	88	83	67	63	229	30	124	108
# LVS:	---	1.3	1.4	1.6	1.5	1.2	1.2	4.2	0.6	2.3	2.0

TT:	89	75	86	97	91	74	69	225	25	100	100
# LVS:	---	1.4	1.6	1.8	1.7	1.4	1.3	4.2	0.5	1.9	1.9

P VE VC GPD/V1/IE V2 V3 V4 V5 R1 R2 R3 R4

Water limiting

P = Planting

VE = Emergence

VC = Cotyledonary Lvs

GPD = Growing Point Differentiation

V1 = 1st Trifoliolate Leaf

IE = Internode Elongation

V2 = 2nd Trifoliolate Leaf

V3= 3rd Trifoliolate Leaf

V4 = 4th Trifoliolate Leaf

V5 = 5th Trifoliolate Leaf

R1 = Beginning Bloom

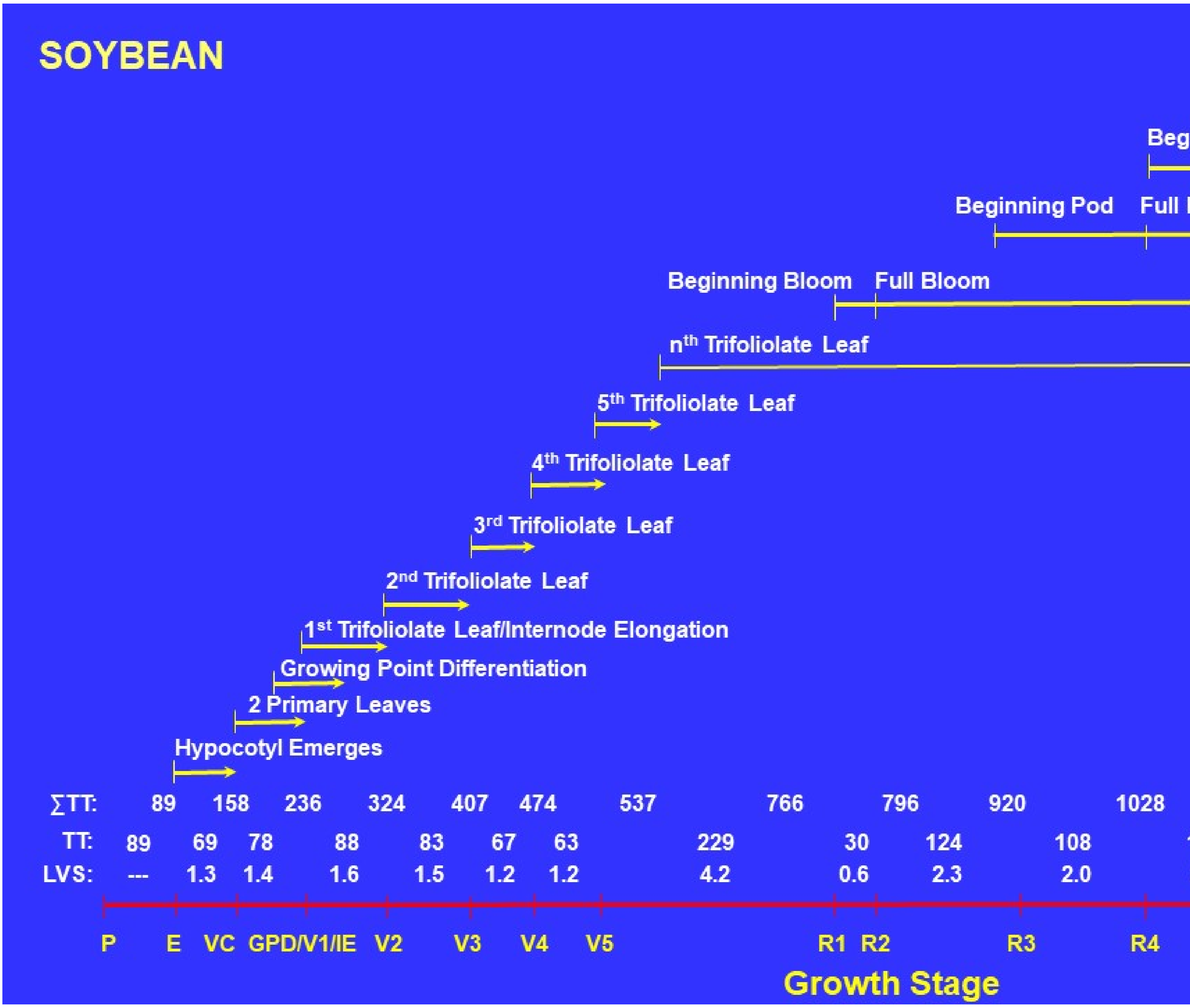
R2 = Full Bloom

R3 = Beginning Pod

R4 = Full Pod

R5 = Beginning Seed

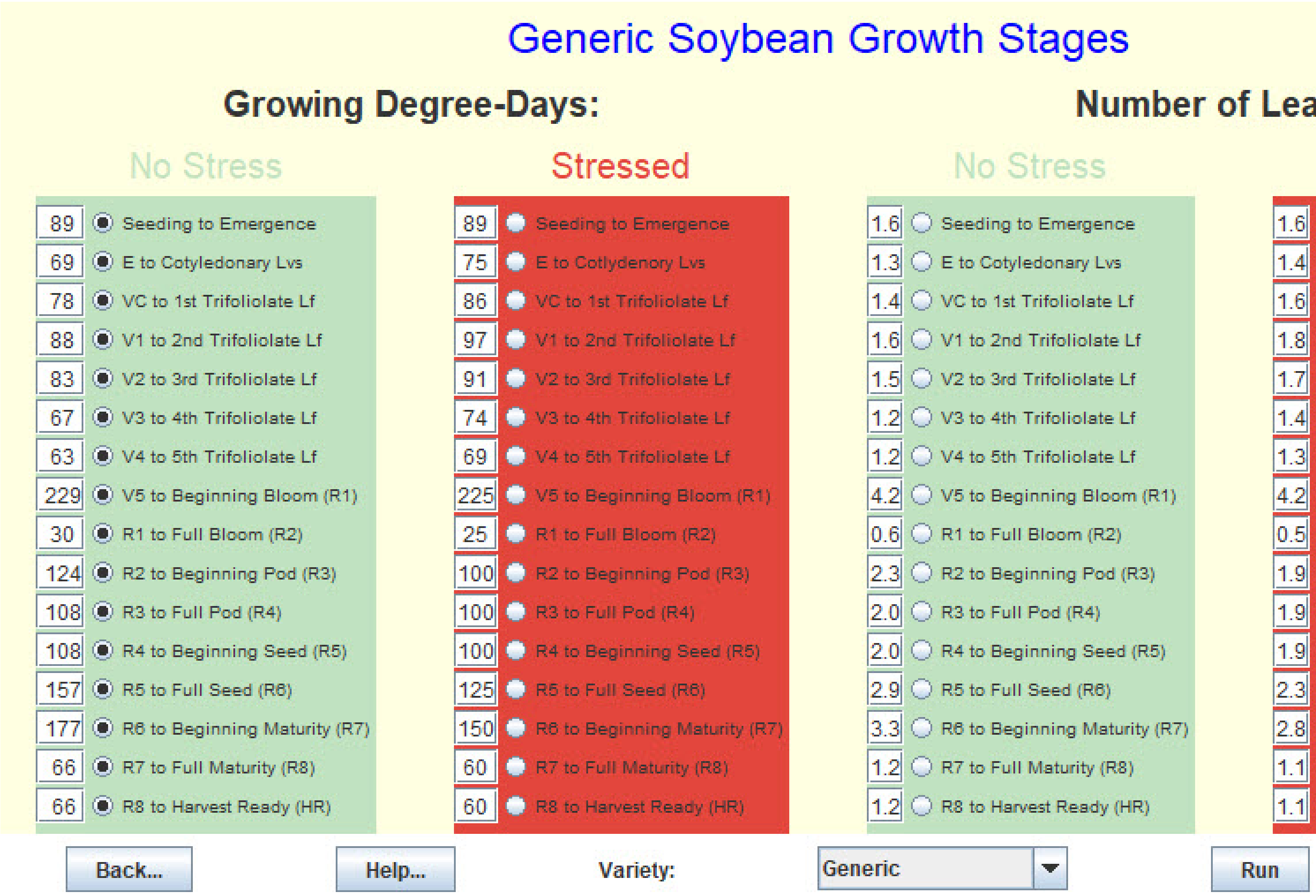
Developmental Sequence



SOYBEAN
Beg
Beginning Pod
Full
Beginning Bloom
Full Bloom
nth Trifoliolate Leaf
5th Trifoliolate Leaf
4th Trifoliolate Leaf
3rd Trifoliolate Leaf
2nd Trifoliolate Leaf
1st Trifoliolate Leaf/Internode Elongation
Growing Point Differentiation
2 Primary Leaves
Hypocotyl Emerges
∑TT: 89 158 236 324 407 474 537 766 796 920 1028
TT: 89 69 78 88 83 67 63 229 30 124 108
LVS: --- 1.3 1.4 1.6 1.5 1.2 1.2 4.2 0.6 2.3 2.0
P E VC GPD/V1/IE V2 V3 V4 V5 R1 R2 R3 R4
Growth Stage

Soybean Growth Stages

The Soybean (*Glycine max (L.) Merr*.) *Growth Stages* screen displayed below shows the parameters for the Generic variety. Please see the [Growth Stages Example] topic for a general description of the growth stages screen.



There are sixteen growth stages for Soybean. The descriptions of the growth stages below came from this [University of Wisconsin] reference for Soybean.

Seeding to *Emergence* (E) - *germination* occurs .The *primary root* grows downward and the *hypocotyl* emerges from the soil pulling the two cotyledons with it. The cotyledons are unifoliate *leaves*. This is also known as VE.

E to *Cotyledonary Leaves* - the hypocotyl straightens out and the cotyledons unfold and expand. This is the beginning of the VC stage and the vegetative phase.

VC to 1st *Trifoliate Leaf* (V1) - the first set of two Trifoliate leaves appear. They originate from the second *node*. The first node was the unifoliolate node.

V1 to 2nd Trifoliate Leaf (V2) - the second set of Trifoliate leaves appear from the third node creating the V2 stage.

V2 to 3rd Trifoliate Leaf (V3) - the third set of Trifoliate leaves appear from the fourth node for the V3 stage.

V4 to 4th Trifoliate Leaf (V4) - the fourth set of Trifoliate leaves appear from the fifth node for the V4 stage.

V4 to 5th Trifoliate Leaf (V5) - the fifth set of Trifoliate leaves appear from the sixth node for the V5 stage. Trifoliate leaves continue to be produced from a new node until VN which is the last node produced. The first branch may develop in the *axil* of the first trifoliate around the V5 stage.

The Reproductive Stages begin when the plants are in the V7 to V10 stages. Many soybean varieties are *indeterminate* and will continue to produce leaves in the *reproductive phase* of development.

Beginning *Bloom* is the first reproductive stage and is known as R1. *Flowering* begins on the *main stem* at the third to the sixth node depending on the V stage of the plant. Flowering then proceeds up and down the main stem from the beginning position of flowering. Branches start to flower a few days after the main stem starts to bloom.

R1 to Full Bloom (R2) - the plant is in the V8 to V12 stages.

R2 to Beginning *Pod* (R3) - pods begin to form on the lower nodes where the first flowers opened. The plant is typically in the V11 to V17 stages.

R3 to Full Pod (R4) - full pod occurs when there is a pod three quarters of an inch long. It is at one of the four uppermost nodes on the main stem with a fully developed leaf. The plant is now in the V13 to V20 stages.

R4 to Beginning *Seed* (R5) - the seed begins to grow rapidly in this stage with nutrients in the plant being distributed to the seeds. This is the period of seed filling. The plant is in the V15 to V23 stages.

R5 to Full Seed (R6) - the beans or 'green beans' are as wide as pod cavity. There are however, beans of all sizes in the pod. The plant is in the V16 to V25 stages. Maximum pod weight on the plant occurs at about R6.

R6 to Beginning Maturity (R7) - beginning maturity is essentially *physiological maturity* because there will be very little increase in dry weight from now on. The seeds and usually the pod have lost their green color but not all have turned color.

R7 to Full Maturity (R8) - full maturity occurs when 95 percent of the pods have attained their mature pod color.

R8 to *Harvest Ready* - after Full Maturity, five to ten days of drying weather are needed for the plant to be ready to harvest. The seeds need to have less than 15 percent moisture.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays several selections based on maturity. The are four general maturity selections for Soybean varieties including *Early Maturity* , *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity* and a number of varieties base on *Maturity Group* ranging from MG 000.5 to MG 10.5. in .5 increments.

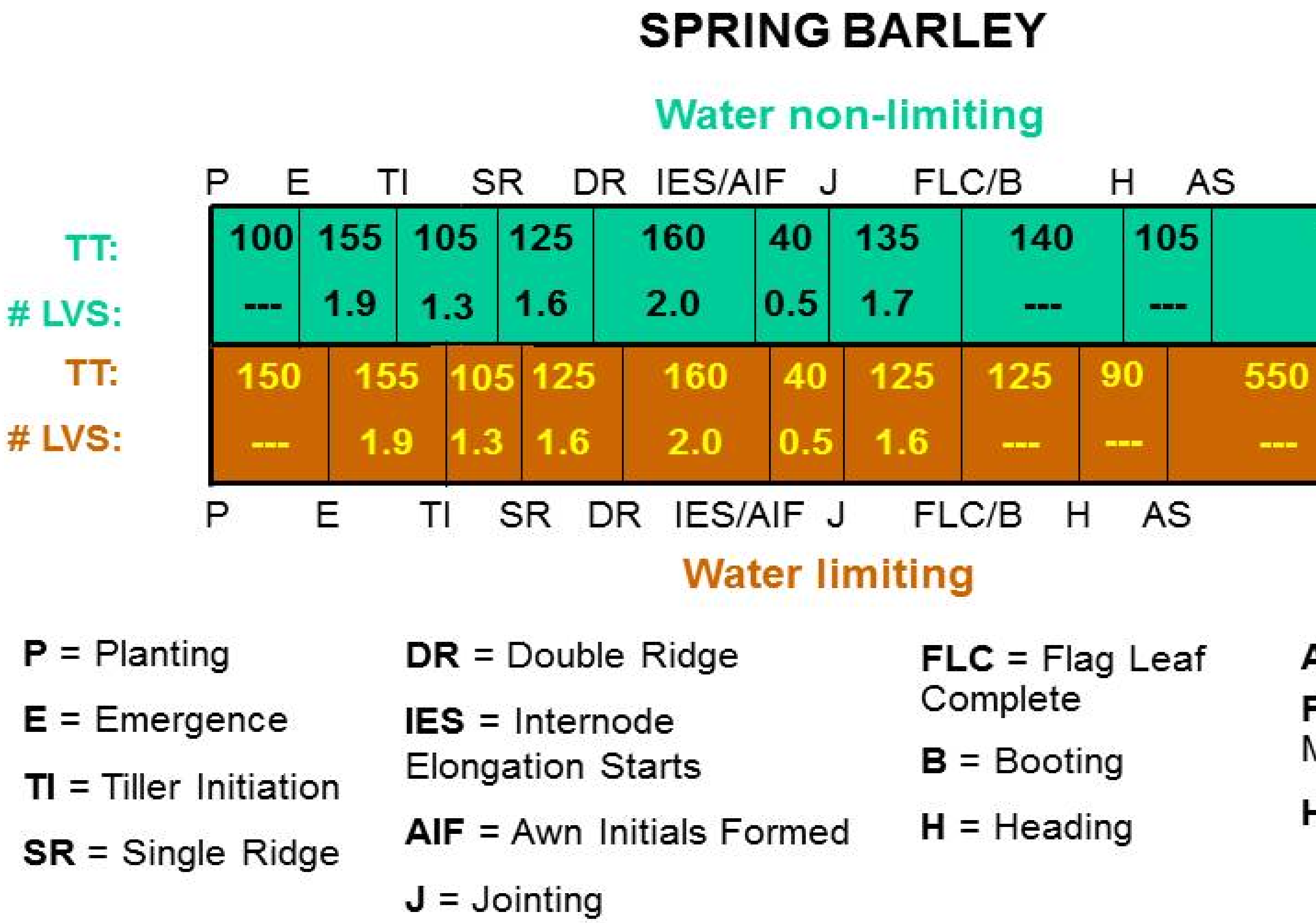
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

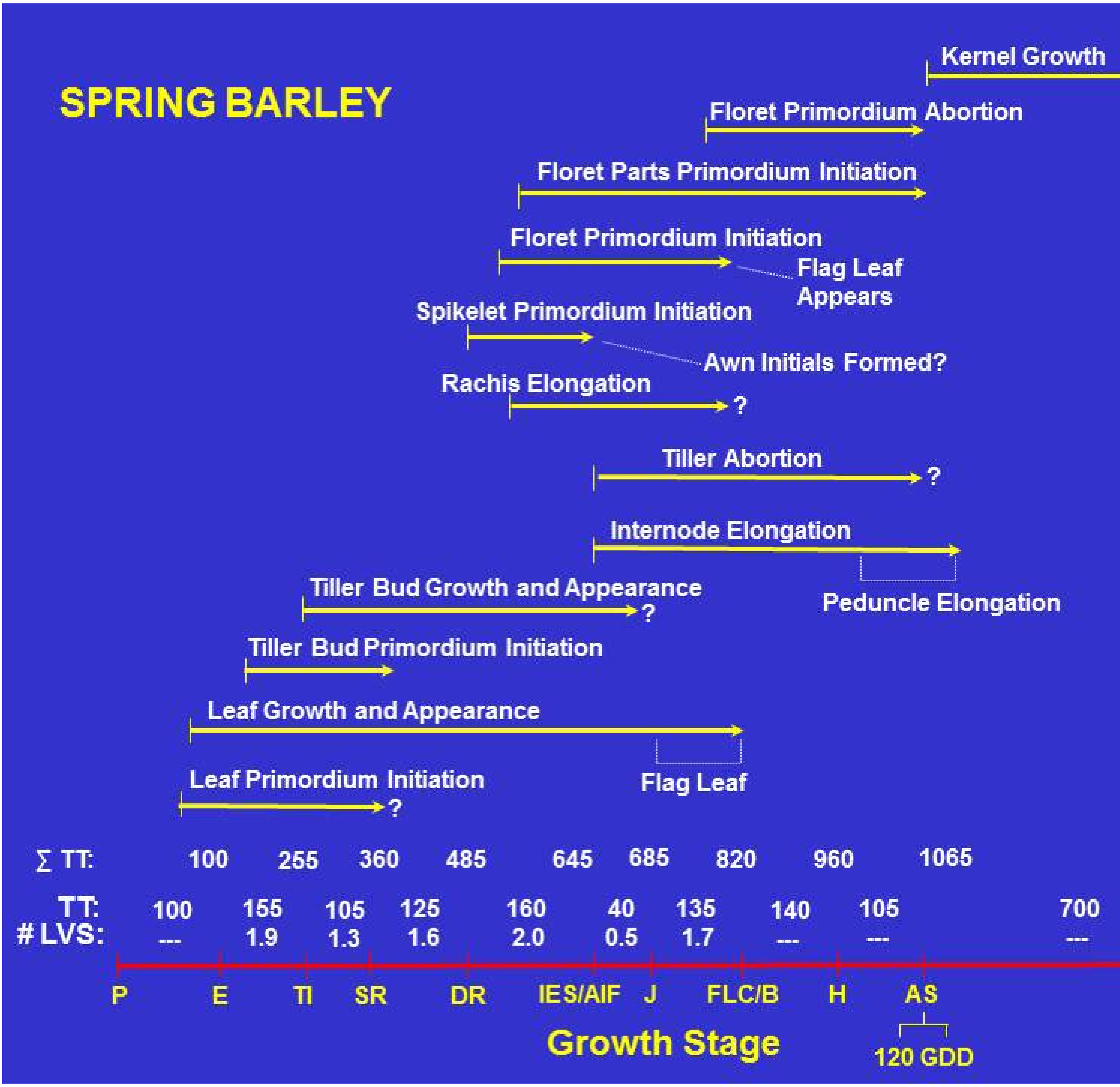
Links to the Phenology Diagram and the Developmental Sequence for Soybean.

Spring Barley Diagrams

Phenology Diagram



Developmental Sequence


SPRING BARLEY
Kernel Growth
Floret Primordium Abortion
Floret Parts Primordium Initiation
Floret Primordium Initiation
Flag Leaf
Appears
Spikelet Primordium Initiation
Awn Initials Formed?
Rachis Elongation
?
Tiller Abortion
?
Internode Elongation
Peduncle Elongation
Tiller Bud Growth and Appearance
?
Tiller Bud Primordium Initiation
Leaf Growth and Appearance
Flag Leaf
Leaf Primordium Initiation
?
∑ TT: 100 255 360 485 645 685 820 960 1065
TT: 100 155 105 125 160 40 135 140 105 700
LVS: --- 1.9 1.3 1.6 2.0 0.5 1.7 --- --- ---
P E TI SR DR IES/AIF J FLC/B H AS
Growth Stage
120 GDD

Spring Barley Growth Stages

The Spring Barley (*Hordeum vulgare* L.) *Growth Stages* screen displayed below shows the parameters for the 8-Leaved variety which is comparable to the Generic variety. Please see the Growth Stages Example topic for a general description of the growth stages screen.

There are eleven *growth* stages for Spring Barley and they are similar to those for Spring Wheat. However, the '*Double Ridge* to *Terminal Spikelet*' stage of Spring Wheat, is replaced with the 'Double Ridge to Awn Initials Formed' stage in Spring Barley. A description of the growth stages follows:

Seeding to *Emergence* (E) - *germination* occurs and the *coleoptile* pushes through to the soil surface. The first main shoot leaf emerges from the coleoptile.

E to First *Tiller* - the first tiller when there are about three *leaves*.

E to *Single Ridge* (*SR*) - the time from emergence to Single Ridge. Single Ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to Double Ridge (*DR*) - the tissue between the single ridges develops into spikelet primordia resulting in the double ridge stage.

DR to *Awn Initials Formed* (*AIF*) - the awn initials are formed in this stage.

AIF to *Jointing* (J) -The *stem* begins to elongate and jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot. The *head* is growing rapidly but is still quite small.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the head and this is referred to as *booting* or Flag Leaf Complete.

FLC to *Heading* (H) - the first *awns* are seen emerging from the *collar* of the flag leaf, heading has begun. The head is pushed out of the flag leaf *sheath*.

H to *Anthesis Starts* (*AS*) -the head is beginning to flower or pollinate. This occurs just before or during head emergence from the flag leaf. *Anthers* are visible at this stage and extruded from the *florets*. *Pollination* occurs beginning with the florets in the central spikelets and progresses to the tip and the base of the barley head.

AS to *Maturity* (M) - once pollination has occurred, the *kernels* progress through three phases of growth during *grain filling*. The first is the "*watery ripe*" and "*milk*" stages. Then the "*soft dough*" phase occurs followed by the "*hard dough*" phase as the kernel approaches maturity. The kernels lose their green color at the hard dough stage. The kernels continue to lose moisture throughout grain filling until they reach 30-40% at physiological maturity. The *glumes* and *peduncle* lose their green color by the time the plant is mature..

M to *Harvest Ready* - the kernels continue to lose moisture and should be harvested when they are at 13 - 14% moisture.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Spring Barley varieties in a general sense based on number of leaves. There are five varieties and include 7-Leaved, 8-Leaved which is equivalent to *Generic*, 9-Leaved, 10-Leaved, and >10-Leaved.

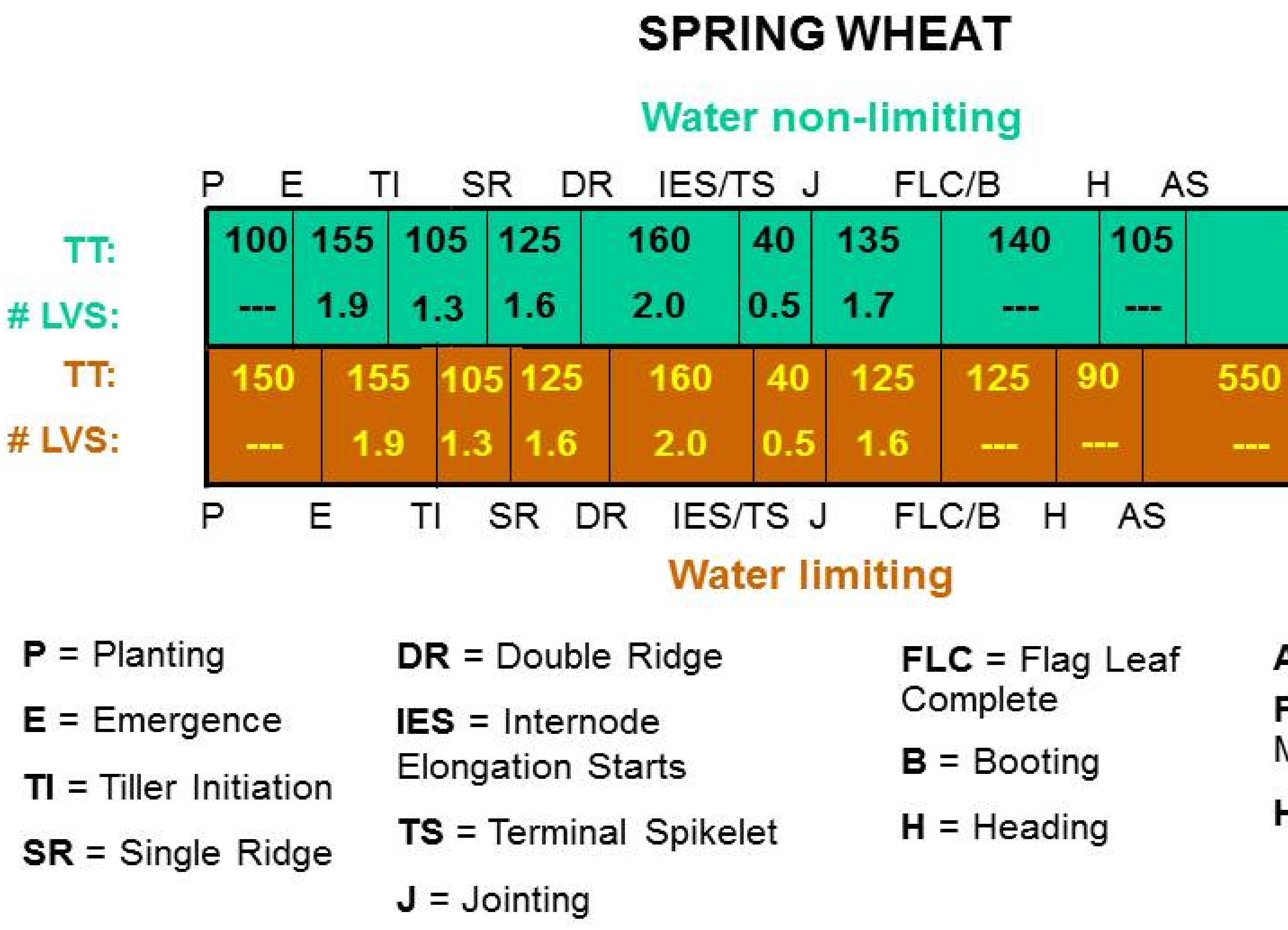
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

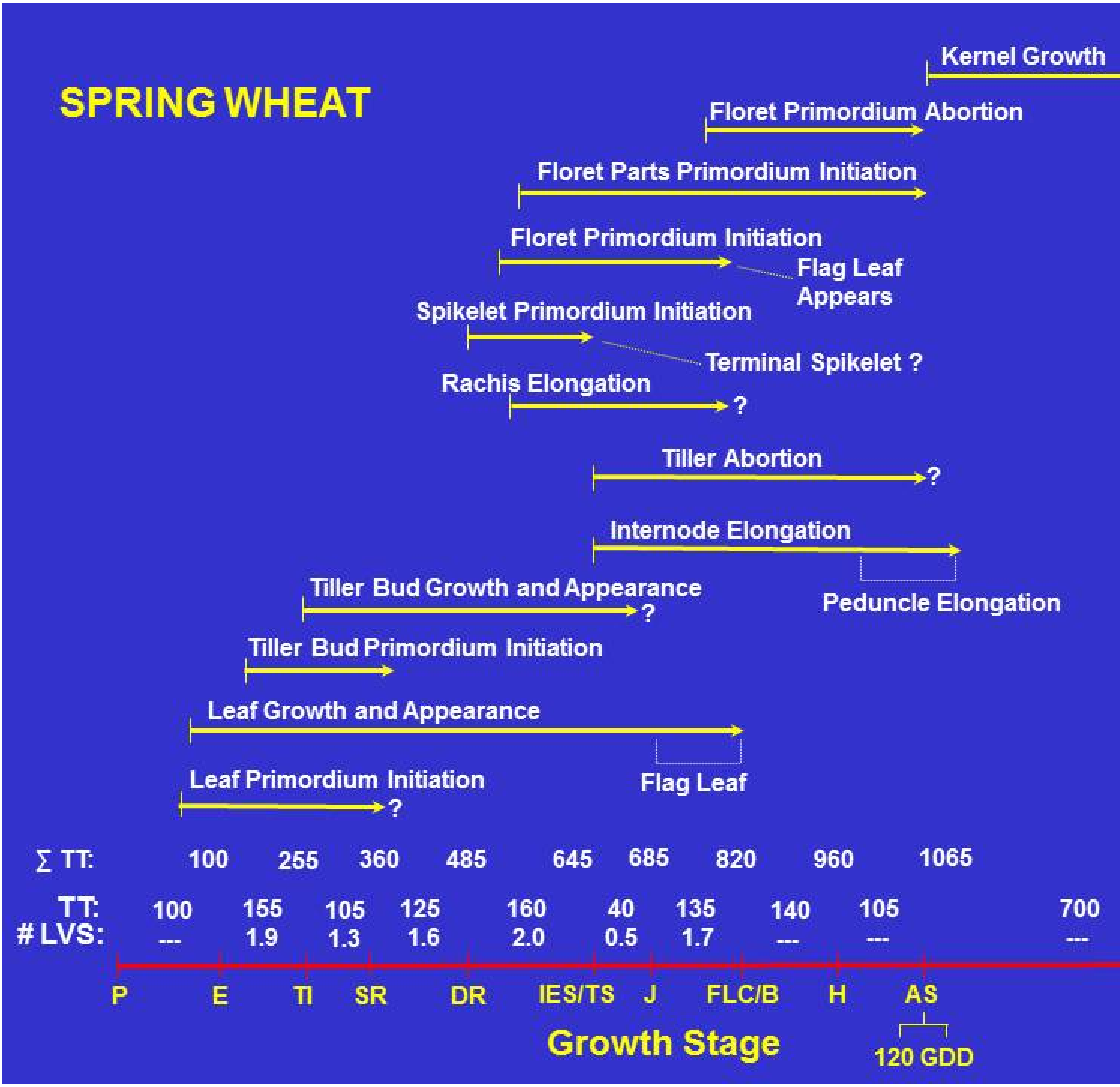
Links to the [Phenology Diagram] and the [Developmental Sequence] for Spring Barley.

Spring Wheat Diagrams

Phenology Diagram



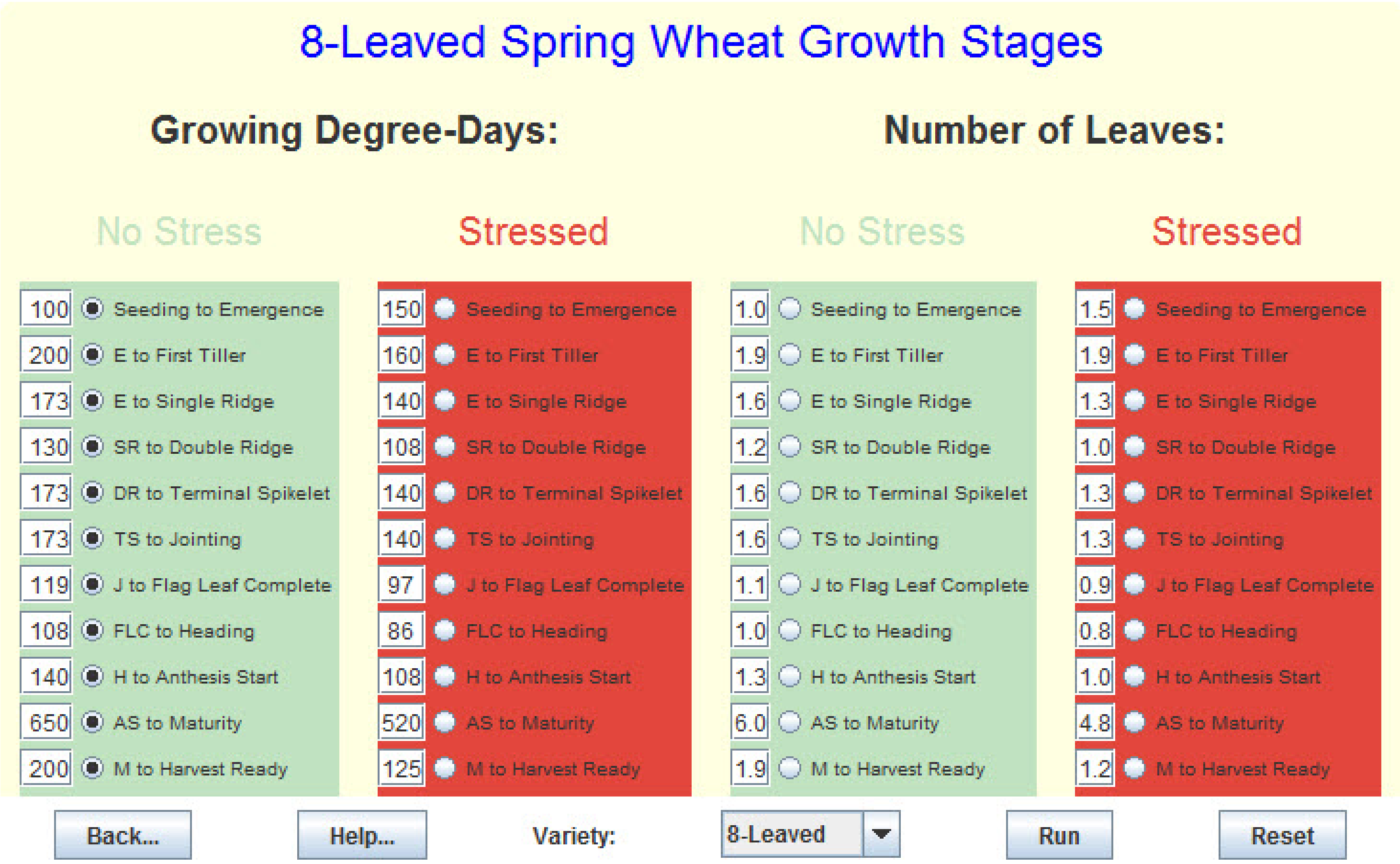
Developmental Sequence



SPRING WHEAT
Kernel Growth
Floret Primordium Abortion
Floret Parts Primordium Initiation
Floret Primordium Initiation
Flag Leaf
Appears
Spikelet Primordium Initiation
Terminal Spikelet ?
Rachis Elongation
?
Tiller Abortion
?
Internode Elongation
Peduncle Elongation
Tiller Bud Growth and Appearance
?
Tiller Bud Primordium Initiation
Leaf Growth and Appearance
Flag Leaf
Leaf Primordium Initiation
?
∑ TT: 100 255 360 485 645 685 820 960 1065
TT: 100 155 105 125 160 40 135 140 105 700
LVS: --- 1.9 1.3 1.6 2.0 0.5 1.7 --- --- ---
P E TI SR DR IES/TS J FLC/B H AS
Growth Stage
120 GDD

Spring Wheat Growth Stages

The Spring Wheat (*Triticum aestivum* L.) *Growth Stages* screen displayed below shows the parameters for the 8-Leaved variety, comparable to the Generic variety. Please see the Growth Stages Example topic for a general description of the growth stages screen.



There are eleven *growth* stages for Spring Wheat and they are identical to those for Winter Wheat but without the overwintering period and the '*Jan 1* to *Single Ridge*' stage. A description of the growth stages follows:

Seeding to *Emergence* (E) - *germination* occurs and the *coleoptile* pushes through to the soil surface. The first true leaf pushes and then emerges from the tip resulting in emergence.

E to First *Tiller* - the first tiller emerges.

E to Single Ridge (*SR*) - Single Ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to *Double Ridge* (*DR*) - the tissue between the single ridges develop into *spikelet* primordia which is the double ridge stage.

DR to *Terminal Spikelet* (TS) - spikelet primordia continue to be initiated with the terminal spikelet *primordium* formed just before *Jointing*.

TS to Jointing (J) - the *head* is fully formed and can be seen inside the *stem* if the stem is cut open. The stem then begins elongating and jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the head and this is referred to as *booting* or Flag Leaf Complete.

FLC to *Heading* (H) - the head is pushed out of the flag leaf *sheath* resulting in heading.

H to *Anthesis Starts* (*AS*) - the head is beginning to flower or pollinate. *Anthers* are visible at this stage and extruded from the *florets*. *Pollination* occurs beginning with the florets in the central spikelets. *Flowering* then progresses up and down the wheat *spike*.

AS to *Maturity* (M) - once pollination has occurred, the *kernels* progress through three phases of growth during *grain filling*. The first is the "*watery ripe*" and "*milk*" stages. Then the "*soft dough*" phase occurs followed by the "*hard dough*" phase as the kernel approaches maturity. The kernels continue to lose moisture throughout grain filling until they reach 30-40% at *physiological maturity*. The head and *peduncle* lose their green color by the time the plant is at maturity.

M to *Harvest Ready* - the kernels continue to lose moisture and should be harvested when they are at 13 - 14% moisture.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Spring Wheat varieties in a general sense based on number of *leaves*. There are five varieties and include 7-Leaved, 8-Leaved which is equivalent to *Generic*, 9-Leaved, 10-Leaved, and >10-Leaved.

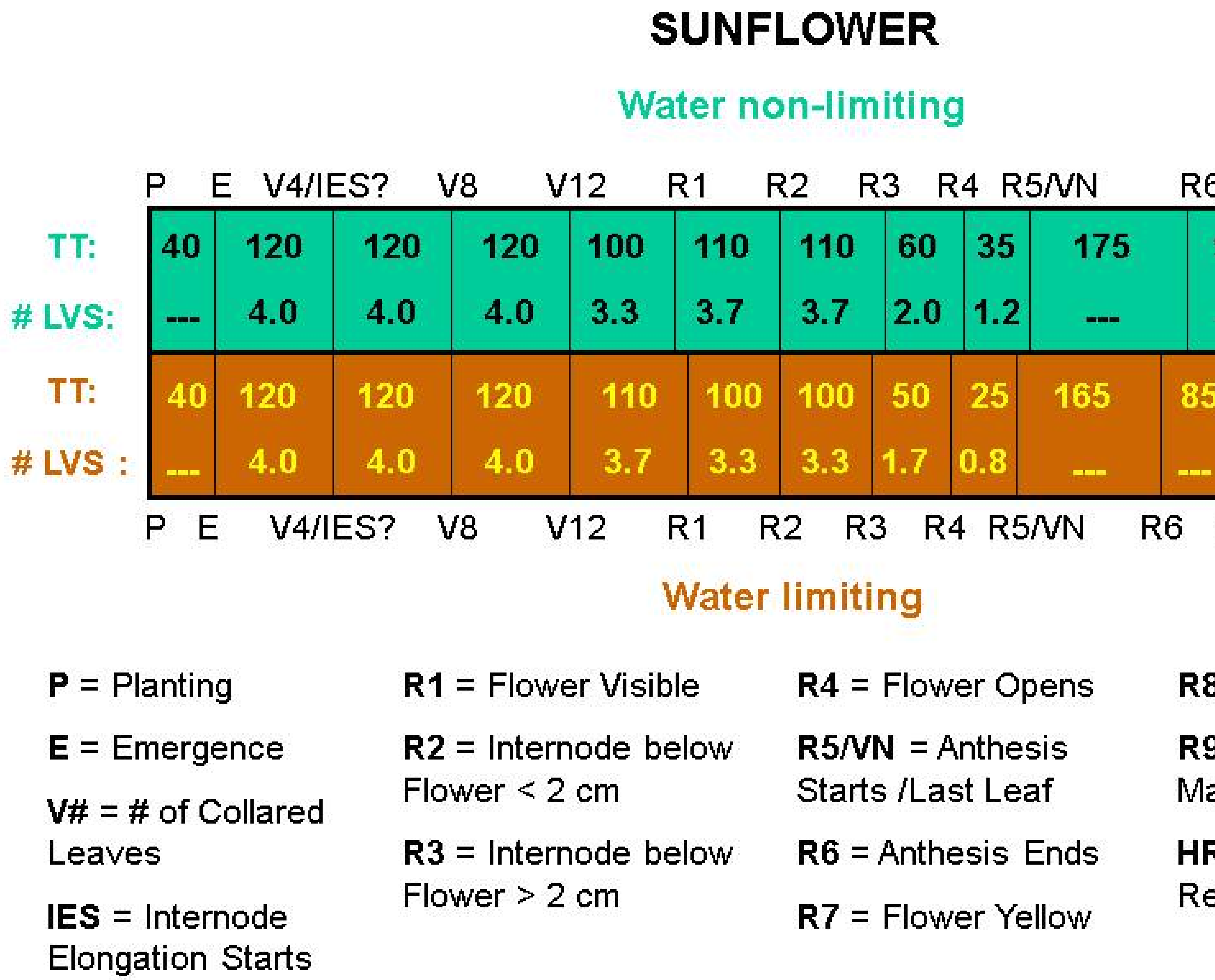
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

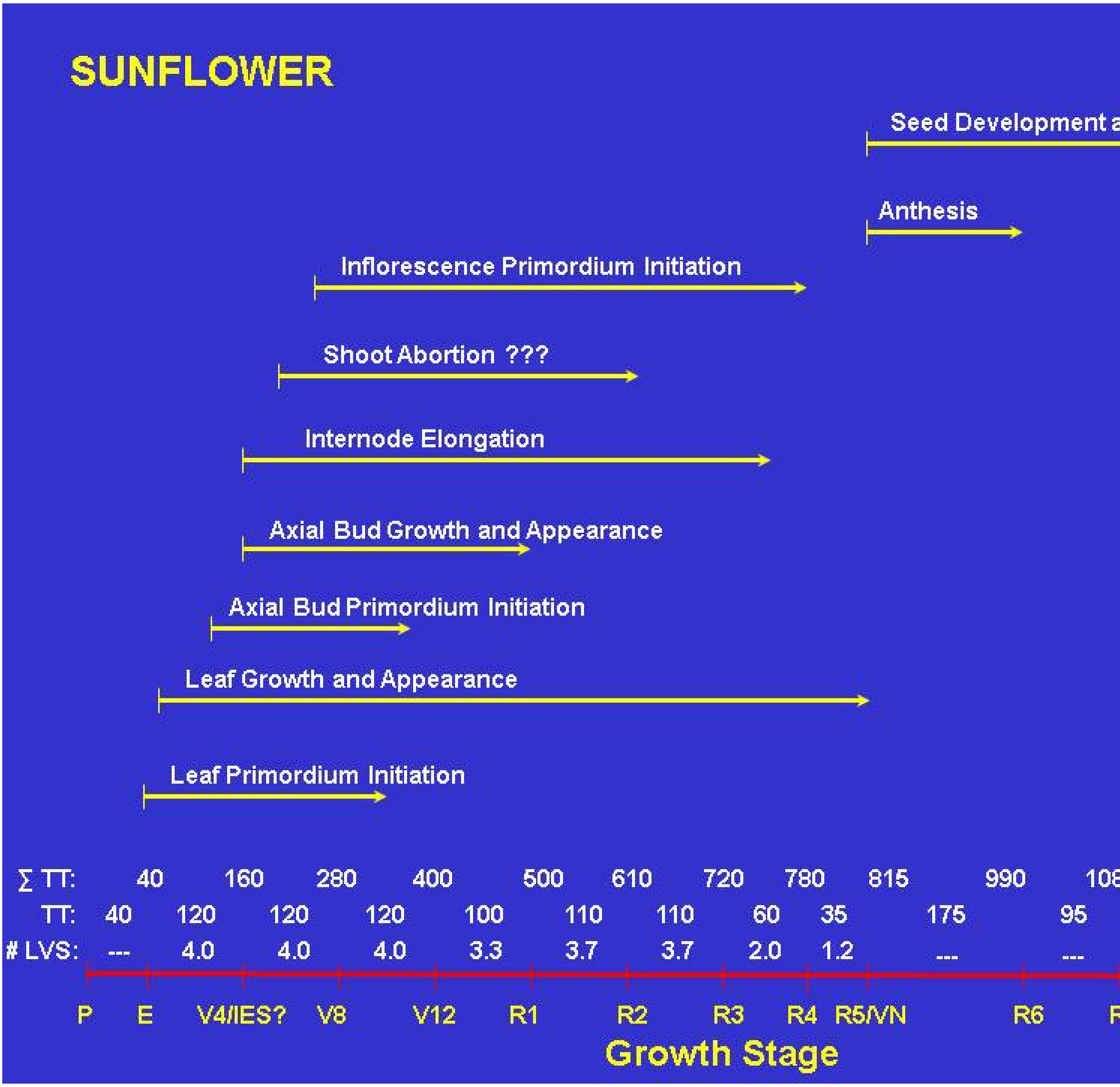
Links to the Phenology Diagram and the Developmental Sequence for Spring Wheat.

Sunflower Diagrams

Phenology Diagram



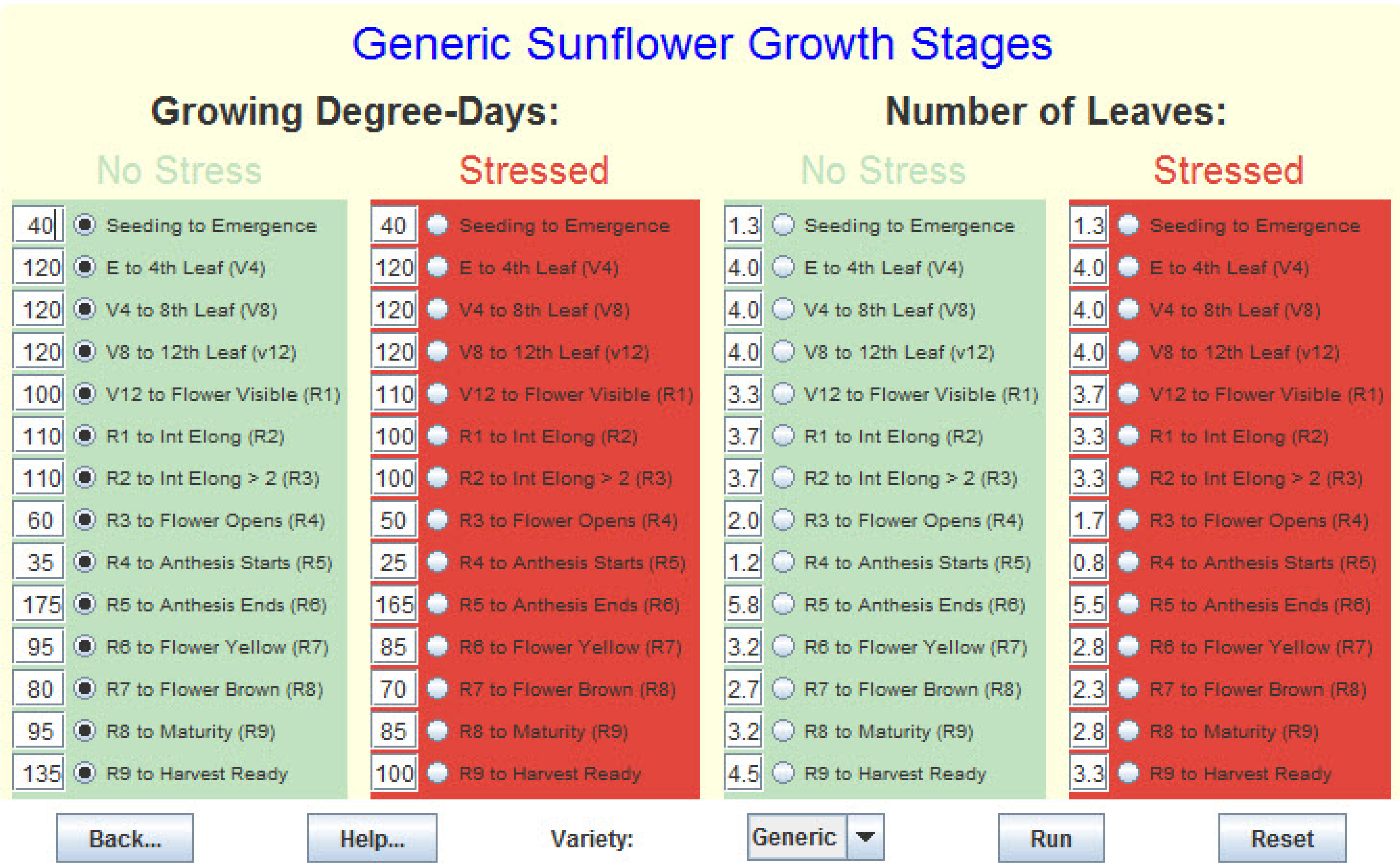
Developmental Sequence



SUNFLOWER
Seed Development a
Anthesis
Inflorescence Primordium Initiation
Shoot Abortion ???
Internode Elongation
Axial Bud Growth and Appearance
Axial Bud Primordium Initiation
Leaf Growth and Appearance
Leaf Primordium Initiation
∑ TT: 40 160 280 400 500 610 720 780 815 990 108
TT: 40 120 120 120 100 110 110 60 35 175 95
LVS: --- 4.0 4.0 4.0 3.3 3.7 3.7 2.0 1.2 --- ---
P E V4/IES? V8 V12 R1 R2 R3 R4 R5/VN R6
Growth Stage

Sunflower Growth Stages

The Sunflower (*Helianthus annuus* L.) *Growth Stages* screen displayed below shows the parameters for the Generic variety. Please see the Growth Stages Example topic for a general description of the growth stages screen.



PhenologyMMS presents fourteen growth stages for sunflower. The following publication was very helpful in the description of each stage: Schneiter, A. A. and J. F. Miller (1981). Description of sunflower growth stages. Crop Sci. **21**(6): 901-903 URL: https://dl.sciencesocieties.org/publications/cs/pdfs/21/6/CS0210060901

Seeding to *Emergence* (E) - at emergence, the *hypocotyl* arch and the cotyledons have pushed through the soil. The first true leaf blade is present but not yet long enough to be counted as a leaf. A leaf blade is considered to be a true leaf when it has attained a length of 4 cm.

E to 4th Leaf (V4) - four *leaves* are present that are 4 cm or greater in length.

V4 to 8th Leaf (V8) - eight leaves are present that are 4 cm or greater in length.

V8 to 12th Leaf (V12) - twelve leaves are present that are 4 cm or greater in length.

V12 to *Flower Visible* (R1) - the *inflorescence* becomes visible. It is surrounded by immature bracts which when viewed from above have a star-like appearance. The appearance of R1 can vary among genotypes with respect to the *number of leaves* already produced.

R1 to *Internode Elongation* (R2) - the internode below the base of the inflorescence and above the nearest leaf that is attached to the *stem*, begins to elongate but is less than 2 cm.

R2 to Internode Elongation > 2 cm (R3) - the internode below the base of the developing *head* continues to elongate and is now greater than 2 cm. It pushes the inflorescence above the surrounding leaves.

R3 to *Flower Opens* (R4) - the inflorescence begins to open making small ray flowers visible.

R4 to *Anthesis Starts* (R5) - the ray flowers are mature and fully extended. All the *disk flowers* are visible. This stage can be divided into substages depending on how many of the disk flowers are in or have completed *anthesis*.

R5 to *Anthesis Ends* (R6) - at this stage, anthesis is finished and the ray flowers are wilting. The ray flowers vary as to whether they wilt and abscise immediately or not.

R6 to *Flower Yellow* (R7) - the back of the head begins to turn a light yellow beginning at the center of the head or it may start at the edge of the head adjacent to the bracts.

R7 to *Flower Brown* (R8) - the back of the head is yellow but may contain some brown spots. The bracts are still green.

R8 to *Maturity* (R9) - the bracts are turning yellow and brown. Much of the back of the head may become brown. This is *physiological maturity* and *seed* moisture is about 35%.

R9 to *Harvest Ready* - the plant is ready for harvest when the seeds are at 14 - 15 % moisture. They need to be dried down to 10% after harvest.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Sunflower varieties in a general sense based on time to maturity and type. There are four varieties relating to maturity and include *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*. Two additional varieties are listed for *Oil* and *Seed sunflowers*.

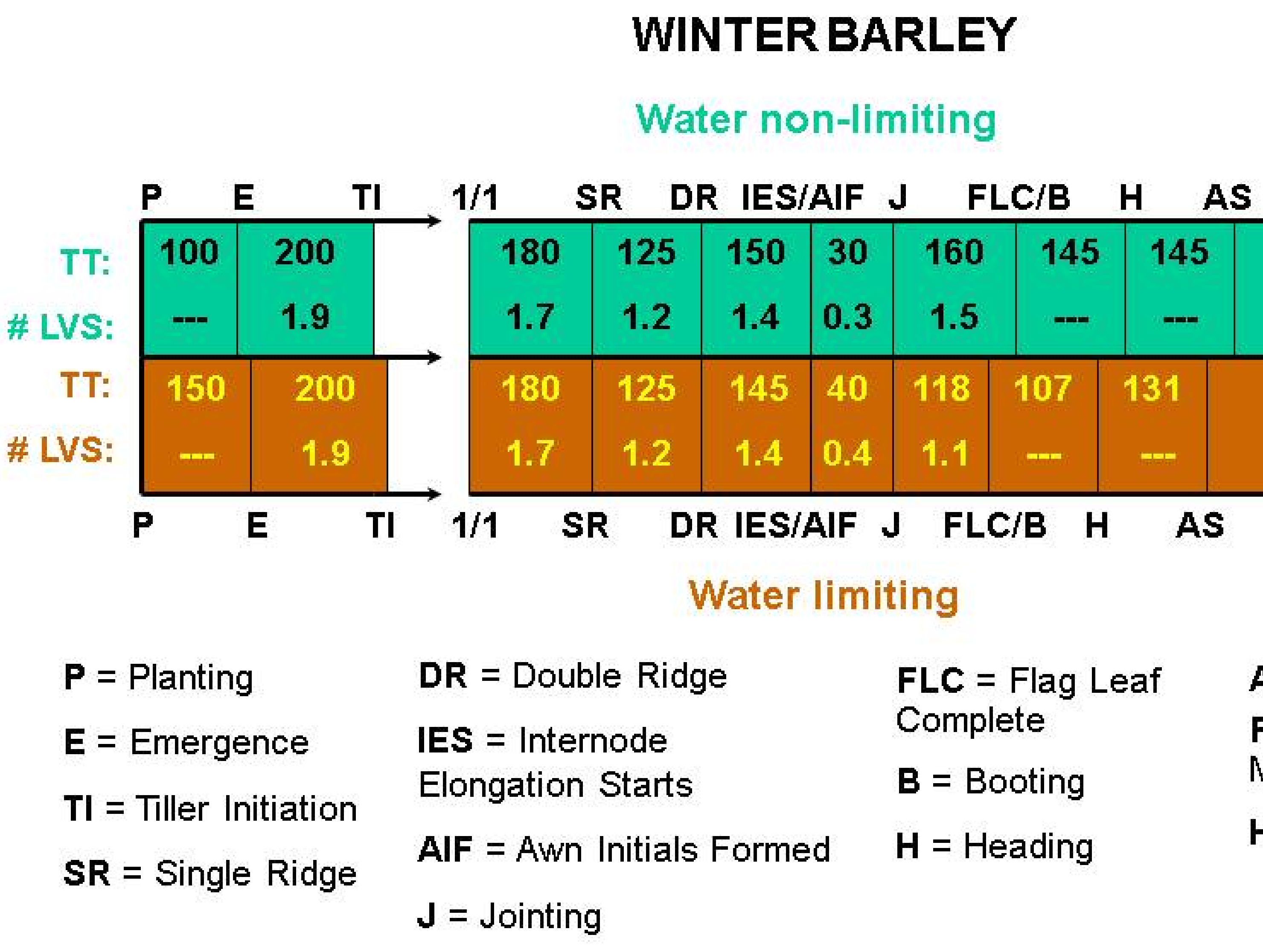
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

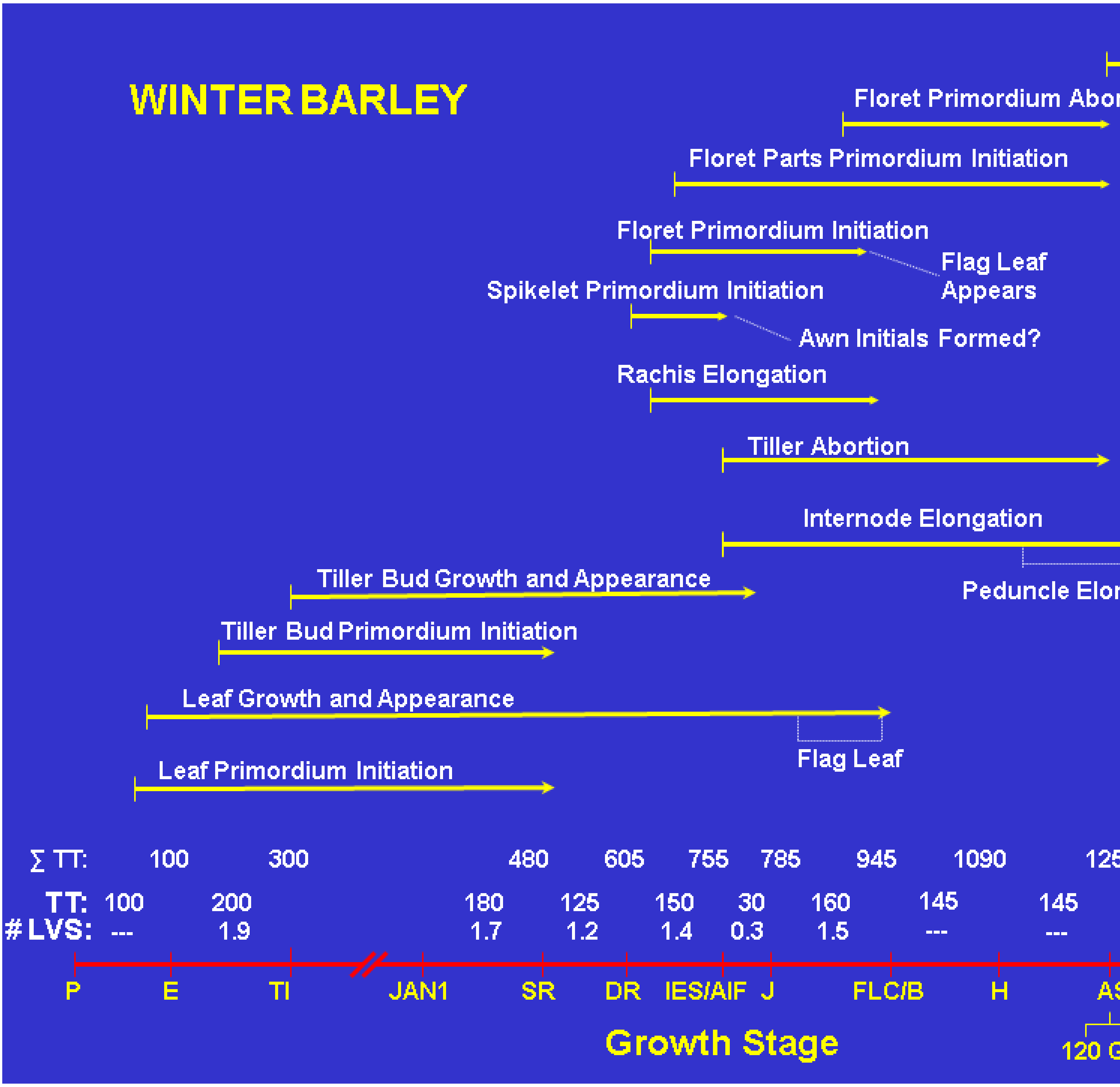
Links to the Phenology Diagram and the Developmental Sequence for Sorghum.

Winter Barley Diagrams

Phenology Diagram



Developmental Sequence



WINTER BARLEY
Floret Primordium Abor
Floret Parts Primordium Initiation
Floret Primordium Initiation
Flag Leaf
Appears
Spikelet Primordium Initiation
Awn Initials Formed?
Rachis Elongation
Tiller Abortion
Internode Elongation
Peduncle Elon
Tiller Bud Growth and Appearance
Tiller Bud Primordium Initiation
Leaf Growth and Appearance
Flag Leaf
Leaf Primordium Initiation
∑ TT: 100 300 480 605 755 785 945 1090 125
TT: 100 200 180 125 150 30 160 145 145
LVS: --- 1.9 1.7 1.2 1.4 0.3 1.5 --- ---
P E TI JAN1 SR DR IES/AIF J FLC/B H AS
Growth Stage
120 G

Winter Barley Growth Stages

The Winter Barley (*Hordeum vulgare* L.) *Growth Stages* screen displayed below shows the parameters for the Generic variety. Please see the Growth Stages Example topic for a general description of the growth stages screen.

There are eleven growth stages for Winter Barley and they are similar to those for Winter Wheat. However, the '*Double Ridge* to *Terminal Spikelet*' stage of Winter Wheat, is replaced with the 'Double Ridge to Awn Initials Formed' stage for Winter Barley. A description of the growth stages follows:

Seeding to *Emergence* (E) - *germination* occurs and the *coleoptile* pushes through to the soil surface. The first main shoot leaf emerges from the coleoptile.

E to First *Tiller* - the time from emergence to the first tiller.

Jan 1 to *Single Ridge* (*SR*) - Jan. 1 is an accepted date in the Northern hemisphere from which to begin accumulation of *growing degree-days* for the growth of the crop. Single Ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to Double Ridge (*DR*) - the tissue between the single ridges develop into spikelet primordia which is the double ridge stage.

DR to *Awn Initials Formed* (*AIF*) - the awn initials are formed in this stage.

AIF to *Jointing* (J) -The *stem* then begins elongating and jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot. The *head* is growing rapidly but is still quite small.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the prominent head and this is referred to as *booting* or Flag Leaf Complete.

FLC to *Heading* (H) - when the first *awns* are seen emerging from the *collar* of the flag leaf, heading has begun. The head is pushed out of the flag leaf *sheath*.

H to *Anthesis Starts* (*AS*) - the head is beginning to flower or pollinate. This occurs just before or during head emergence from the flag leaf. *Anthers* are visible at this stage and extruded from the *florets*. *Pollination* occurs beginning with the florets in the central spikelets and progresses to the tip and the base of the barley head.

AS to *Maturity* (M) - once pollination has occurred, the *kernels* progress through three phases of growth during *grain filling*. The first is the "*watery ripe*" and "*milk*" stages. Then the "*soft dough*" phase occurs followed by the "*hard dough*" phase as the kernel approaches maturity. The kernels lose their green color at the hard dough stage. The kernels lose moisture throughout grain filling and are between 30-40% at *physiological maturity*. The *glumes* and *peduncle* lose their green color by the time the plant is mature.

M to *Harvest Ready* - the kernels continue to lose moisture and should be harvested when they are at 13 - 14% moisture.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays the available selections of Winter Barley varieties in a general sense based on time to maturity. There are four varieties and include *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*.

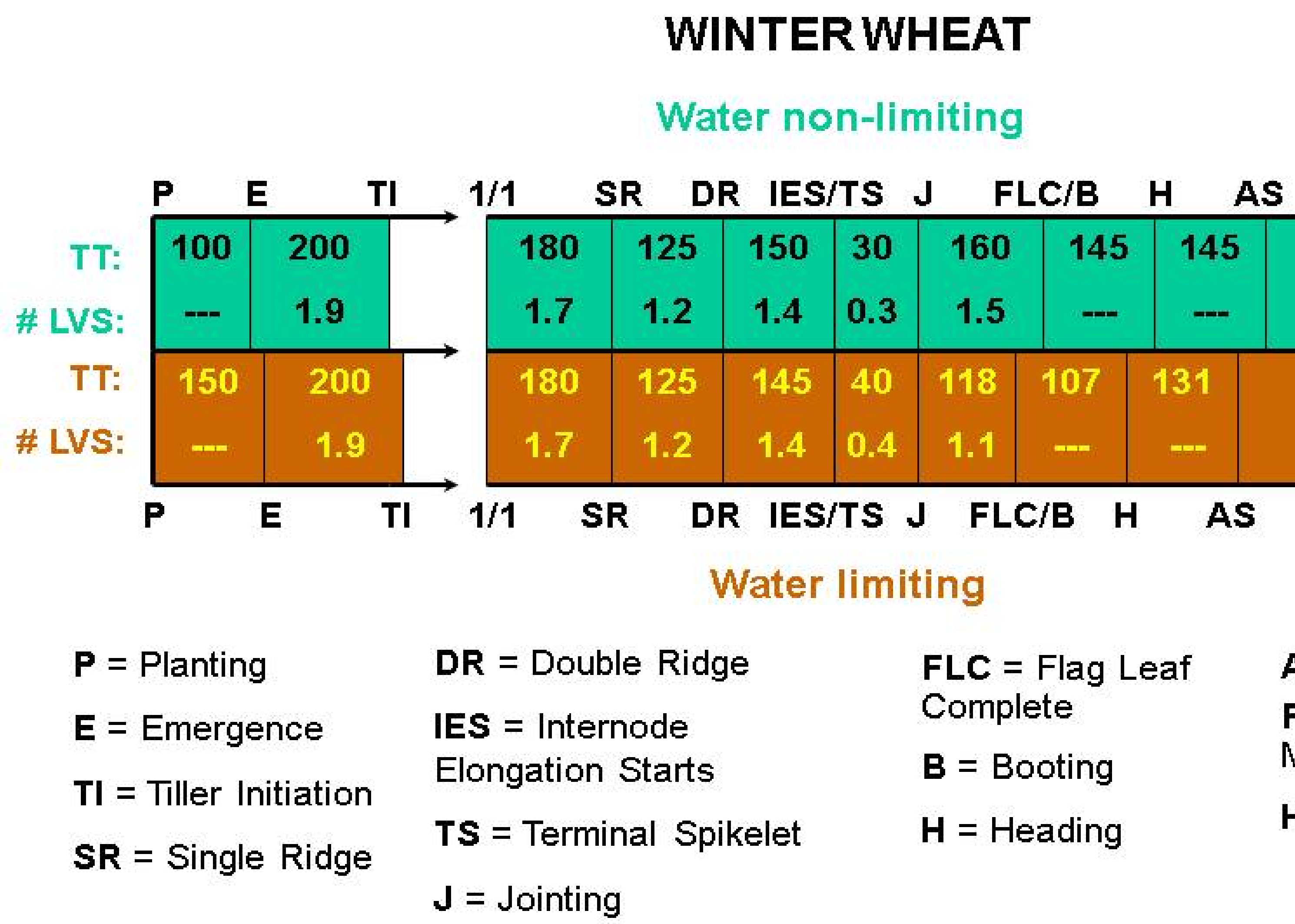
The *Run*... button executes the program with the selections that have been chosen.

The Reset button sets all the values in the columns back to their original, default values.

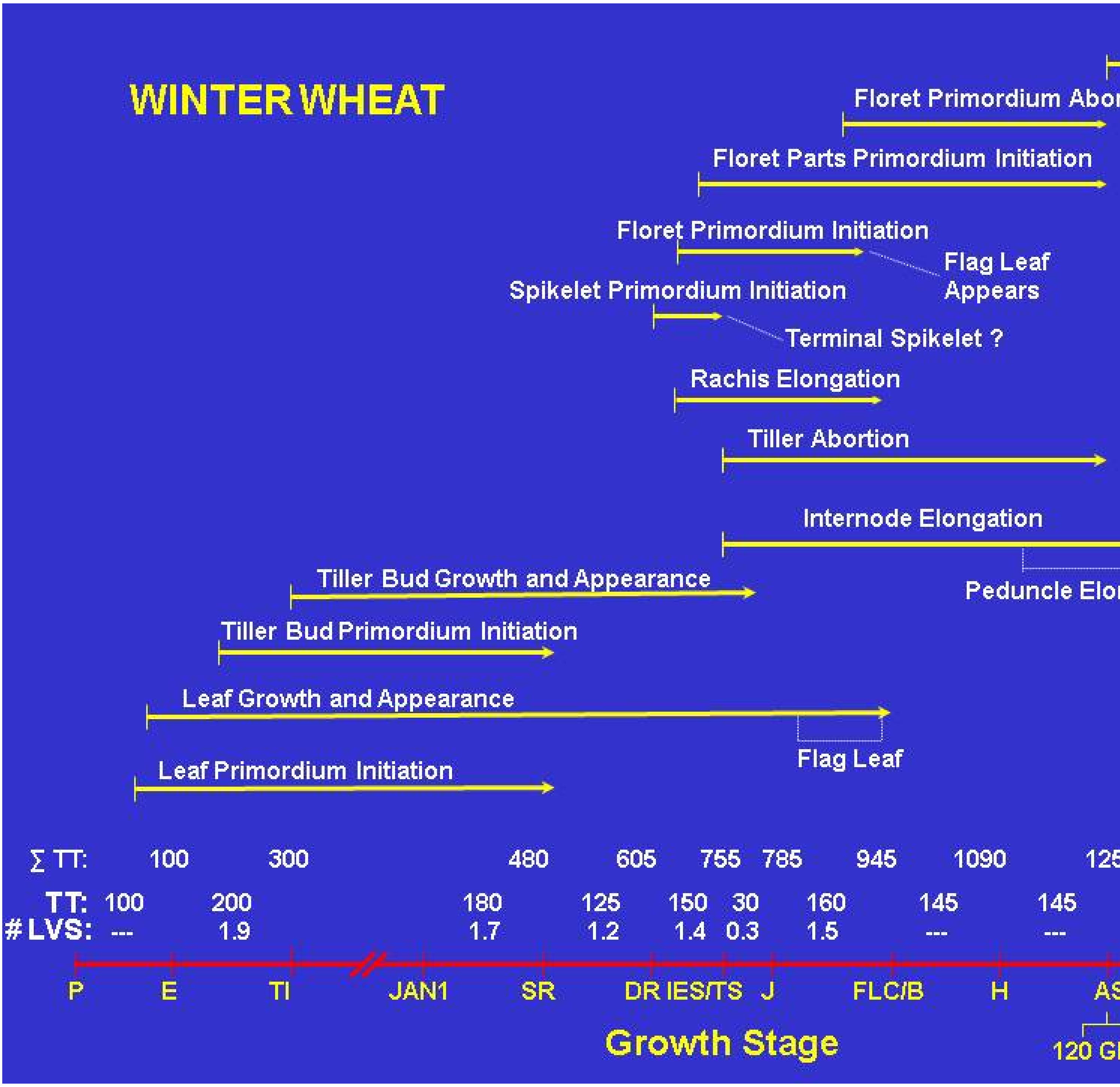
Links to the Phenology Diagram and the Developmental Sequence for Winter Barley.

Winter Wheat Diagrams

Phenology Diagram



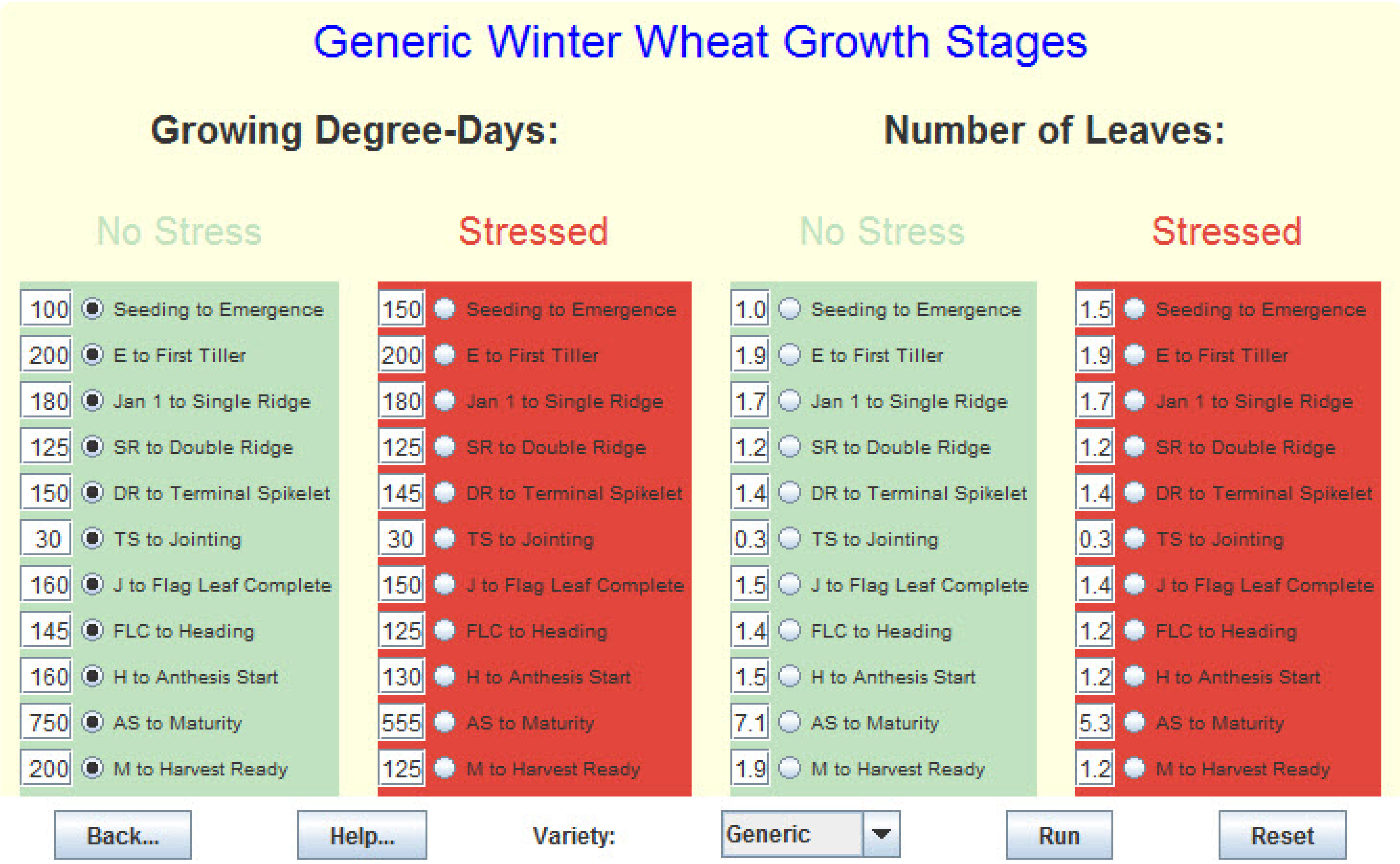
Developmental Sequence



WINTER WHEAT
Floret Primordium Abor
Floret Parts Primordium Initiation
Floret Primordium Initiation
Flag Leaf Appears
Spikelet Primordium Initiation
Terminal Spikelet ?
Rachis Elongation
Tiller Abortion
Internode Elongation
Peduncle Elon
Tiller Bud Growth and Appearance
Tiller Bud Primordium Initiation
Leaf Growth and Appearance
Flag Leaf
Leaf Primordium Initiation
∑ TT: 100 300 480 605 755 785 945 1090 125
TT: 100 200 180 125 150 30 160 145 145
LVS: --- 1.9 1.7 1.2 1.4 0.3 1.5 --- ---
P E TI JAN1 SR DR IES/TS J FLC/B H AS
Growth Stage
120 GI

Winter Wheat

The Winter Wheat (*Triticum aestivum* L.) *Growth Stages* screen displayed below shows the parameters for the Generic variety. Please see the [Growth Stages Example] topic for a general description of the growth stages screen.



There are eleven growth stages for winter wheat. Many of the cereal grasses follow this pattern of growth.

Seeding to *Emergence* (E) - *germination* occurs and the *coleoptile* pushes through to the soil surface. The first true leaf pushes and then emerges from the tip resulting in emergence.

E to First *Tiller* - the first tiller emerges.

Jan 1 to *Single Ridge* (*SR*) - Jan. 1 is an accepted date in the Northern hemisphere from which to begin accumulation of *growing degree-days* for the growth of the crop. Single Ridge occurs when the *shoot apex* first elongates. Subsequent leaf primordia cease further *development* and they form a single ridge around the apex.

SR to *Double Ridge* (*DR*) - the tissue between the single ridges develop into *spikelet* primordia which is the double ridge stage.

DR to *Terminal Spikelet* (TS) - spikelet primordia continue to be initiated until the last or terminal spikelet *primordium* is formed just before *Jointing*.

TS to Jointing (J) - the *head* is fully formed and can be seen inside the *stem* if the stem is cut open. The stem then begins elongating and jointing occurs when the first *node* is visible just above the soil line or at the base of the shoot.

J to *Flag Leaf Complete* (*FLC*) - the *flag leaf* is the last leaf to emerge from the *whorl* and is completely emerged when the leaf's *ligule* is visible. It encloses the head and this is referred to as *booting* or Flag Leaf Complete.

FLC to *Heading* (H) - the head is pushed out of the flag leaf *sheath* resulting in heading.

H to *Anthesis Starts* (*AS*) - the head is beginning to flower or pollinate. *Anthers* are visible at this stage and extruded from the *florets*. *Pollination* occurs beginning with the florets in the central spikelets. *Flowering* then progresses up and down the wheat *spike*.

AS to *Maturity* (M) - once pollination has occurred, the *kernels* progress through three phases of growth during *grain filling*. The first is the "*watery ripe*" and "*milk*" stages. Then the "*soft dough*" phase occurs followed by the "*hard dough*" phase as the kernel approaches maturity. The kernels lose moisture throughout grain filling and are between 30-40% at *physiological maturity*. The head and *peduncle* lose their green color by the time the plant is at maturity.

M to *Harvest Ready* - the kernels continue to lose moisture and should be harvested when they are at 13 - 14% moisture.

The Back... button will take you back to the previous screen .

The Help... button opens a screen displaying help for this screen.

The Variety drop down list displays four available selections of Winter Wheat varieties in a general sense based on time to maturity including *Early Maturity*, *Medium Maturity* and *Generic* which are equivalent, and *Late Maturity*. Several named varieties follow in the list with designations following the name which refer to whether they are hard red winter (*HRW*) or hard white winter (*HWW*) types followed by maturity designations including Early Maturity (*EM*), Medium Maturity (*MM*), and Late Maturity (*LM*). An additional designation refers to the plant height with Short (S), Medium (M) and Tall (T) being the choices. Following these varieties are several older named varieties which do not have the previous designations.

The *Run*... button executes the program with the selections that have been chosen.

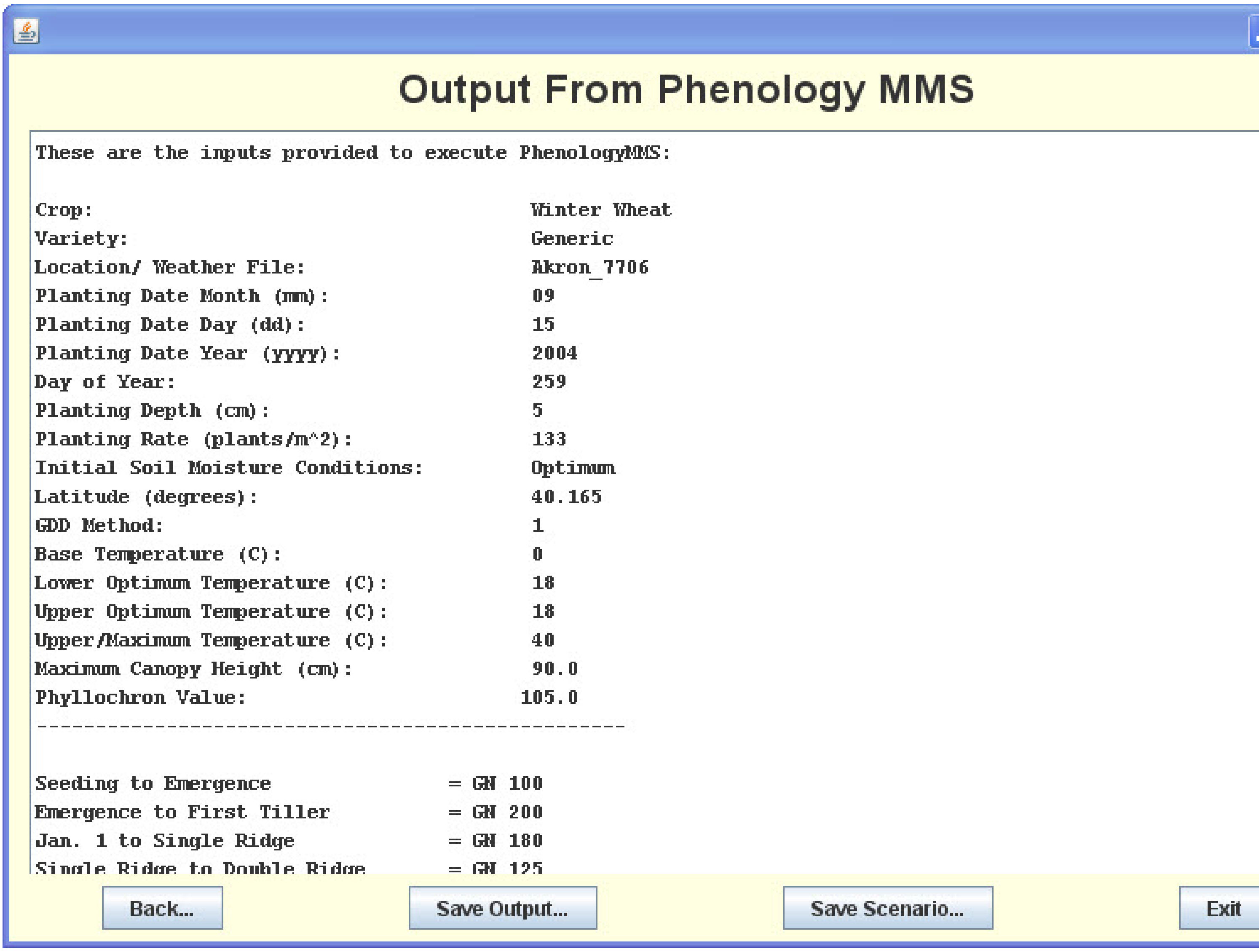
The Reset button sets all the values in the columns back to their original, default values.

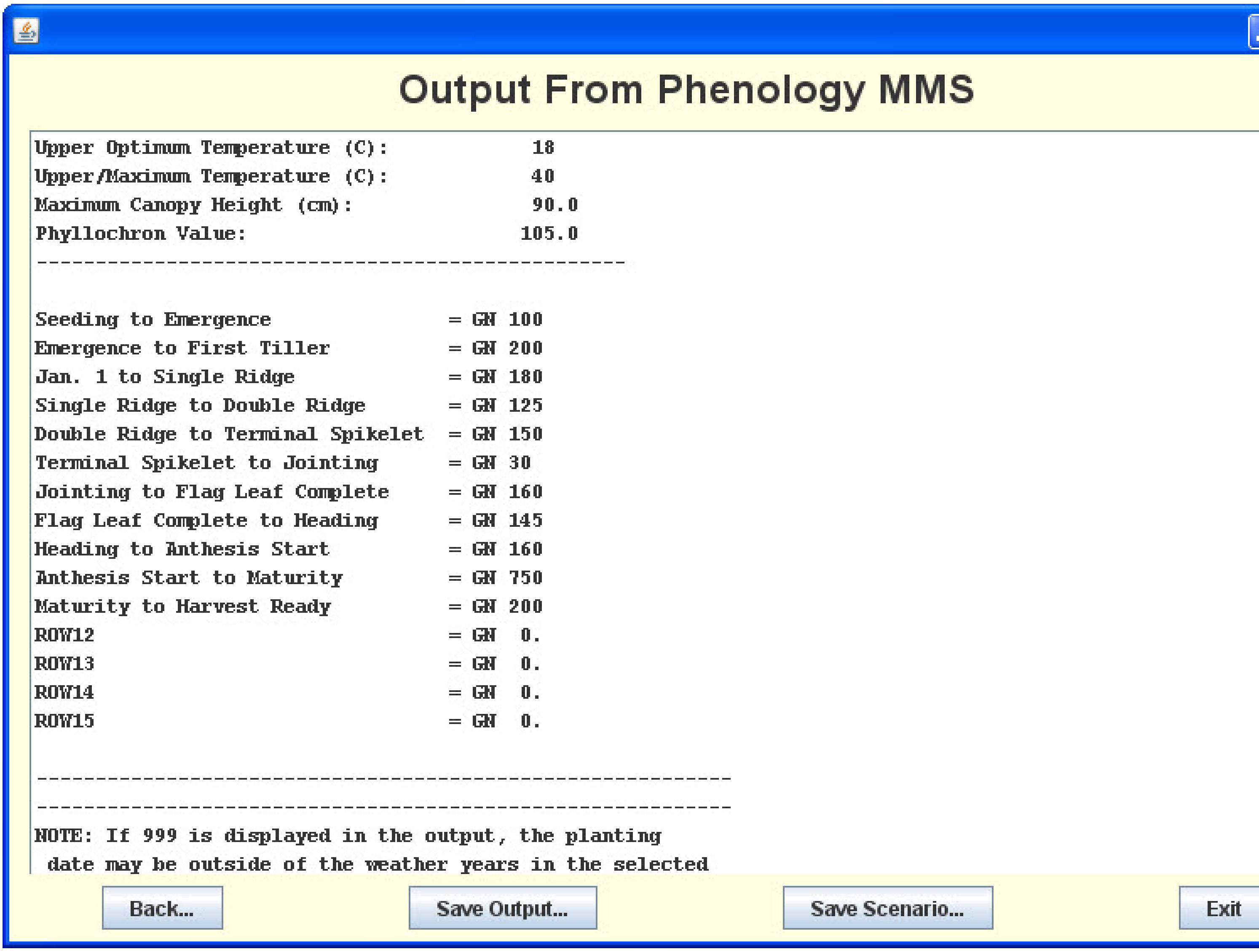
Links to the Phenology Diagram and the Developmental Sequence for Winter Wheat.

Output

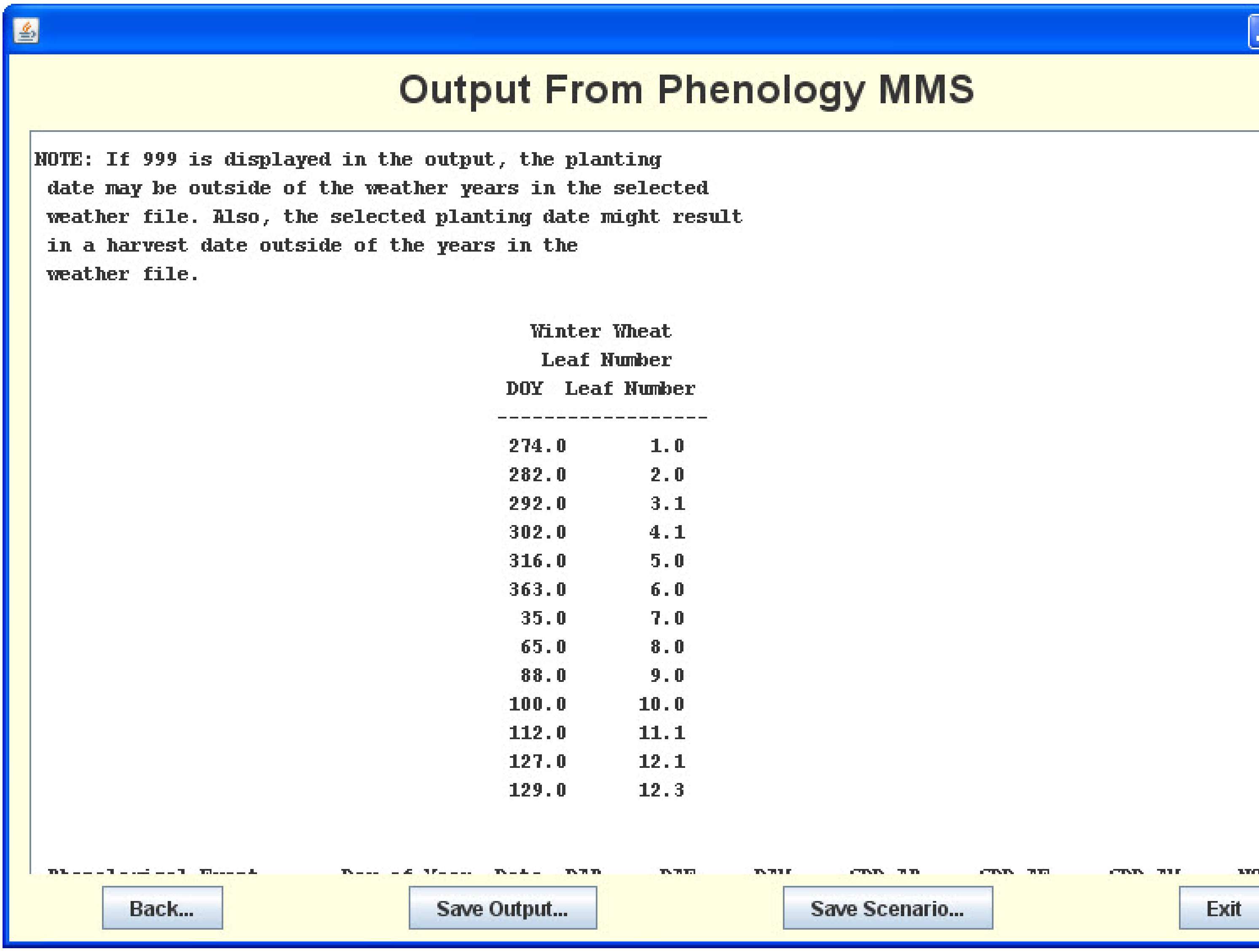
The ‘Output From PhenologyMMS’ screen contains the information for the model *run*, as well as the output from the run.

The top portion of the screen, as seen in the next two images, contains all *inputs* provided to the model including the parameters from the *Growth Stages* screen.





The middle portion of the Output screen shows the Note concerning the display of 999 in the output which may be due to the planting date being selected outside the range of the weather years in the selected *weather file* (meaning weather data were not available). A portion of the *Leaf Number* table is then displayed which shows the increase in number of leaves and the corresponding *day of year* (*DOY*) when this amount occurred. The *number of leaves* is incremented only when the next integer is reached, therefore there is a gap in time between DOY of one leaf and DOY of the next leaf. The number of leaves continues to increment until the end of leaf growth. The growth stage at which this occurs varies between crops.



At the bottom of the Output screen, the Phenology table is displayed. This table shows for each Phenological Event (i.e., Growth stage) the day of year (DOY), date, days after planting (*DAP*), days after emergence (*DAE*), days after *vernalization* (*DAV*), *GDD* from planting (GDD AP), GDD from emergence (*GDD AE*), GDD from vernalization (*GDD AV*), and number of leaves that had appeared (*LN*) when that event occurred. Not all columns apply to all crops. For example, those crops not requiring vernalization will not have a DAV or GDD AV column. The number of leaves is displayed for each growth stage up to and including the stage where leaf growth ends. For every stage thereafter, the number remains the same as the maximum number achieved at the end of the leaf growth stage.

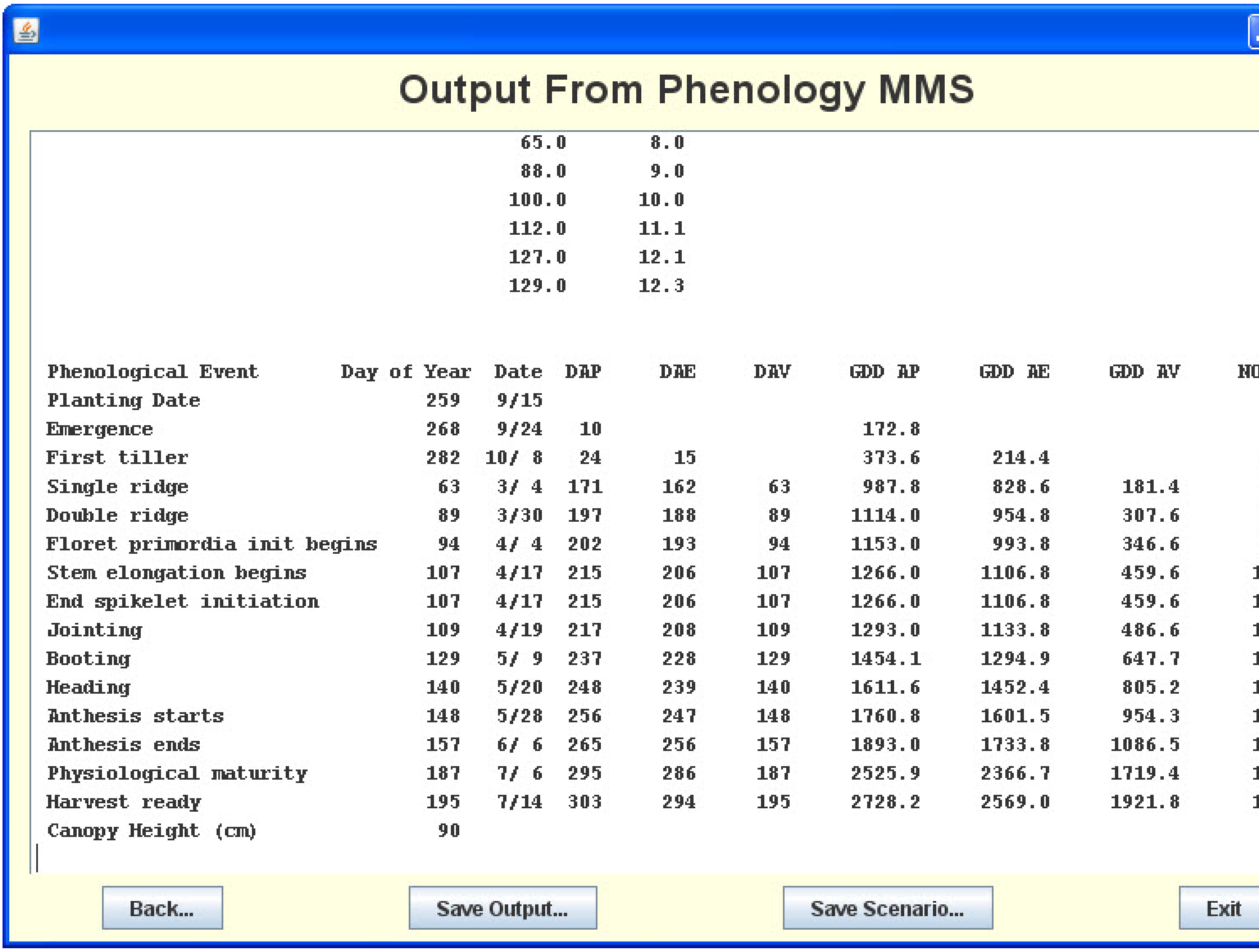
The Maximum *Canopy Height* for the crop is displayed at the bottom of the table.

There are several buttons at the bottom of the screen:

The ‘Back…’ button - takes you back to the first screen, ‘Begin Setup’. You can then set up a new run and run a different *scenario* or Load a Saved Scenario.

The ‘Save Output …’ button - opens the [‘Save Output From Current Run’] dialog box where you can save the output from the current run. It is usually saved in the 'results' folder and the saved file contains only the *Leaf Number table* and the *Phenology table*.

The ‘Save Scenario…’ button opens the [‘Save Current Scenario’] dialog box to the ‘saves’ folder. This saves all the input data used to run the current crop and produce the current output. This saved file will then be in the list of scenarios that you can choose from in the [‘Begin Setup’] screen. NOTE: to see this new scenario in the listing, exit the program and restart it to update the list so that it includes the new scenario.



Output From Phenology MMS

65.0	8.0
88.0	9.0
100.0	10.0
112.0	11.1
127.0	12.1
129.0	12.3

Phenological Event	Day of Year	Date	DAP	DAE	DAV	GDD AP	GDD AE	GDD AV	NO
Planting Date	259	9/15							
Emergence	268	9/24	10			172.8			
First tiller	282	10/ 8	24	15		373.6	214.4		
Single ridge	63	3/ 4	171	162	63	987.8	828.6	181.4	
Double ridge	89	3/30	197	188	89	1114.0	954.8	307.6	
Floret primordia init begins	94	4/ 4	202	193	94	1153.0	993.8	346.6	
Stem elongation begins	107	4/17	215	206	107	1266.0	1106.8	459.6	1
End spikelet initiation	107	4/17	215	206	107	1266.0	1106.8	459.6	1
Jointing	109	4/19	217	208	109	1293.0	1133.8	486.6	1
Booting	129	5/ 9	237	228	129	1454.1	1294.9	647.7	1
Heading	140	5/20	248	239	140	1611.6	1452.4	805.2	1
Anthesis starts	148	5/28	256	247	148	1760.8	1601.5	954.3	1
Anthesis ends	157	6/ 6	265	256	157	1893.0	1733.8	1086.5	1
Physiological maturity	187	7/ 6	295	286	187	2525.9	2366.7	1719.4	1
Harvest ready	195	7/14	303	294	195	2728.2	2569.0	1921.8	1
Canopy Height (cm)	90								

Back... Save Output... Save Scenario... Exit

Press the ‘Exit’ button to close the program.

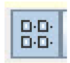
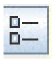
Links to: [Overview]

Save Output

This screen is accessed from the ‘Save Output’ button on the [‘Output From PhenologyMMS’ screen](). This selection saves only the Output from the Current *Run*. Setup parameters and values are not included.

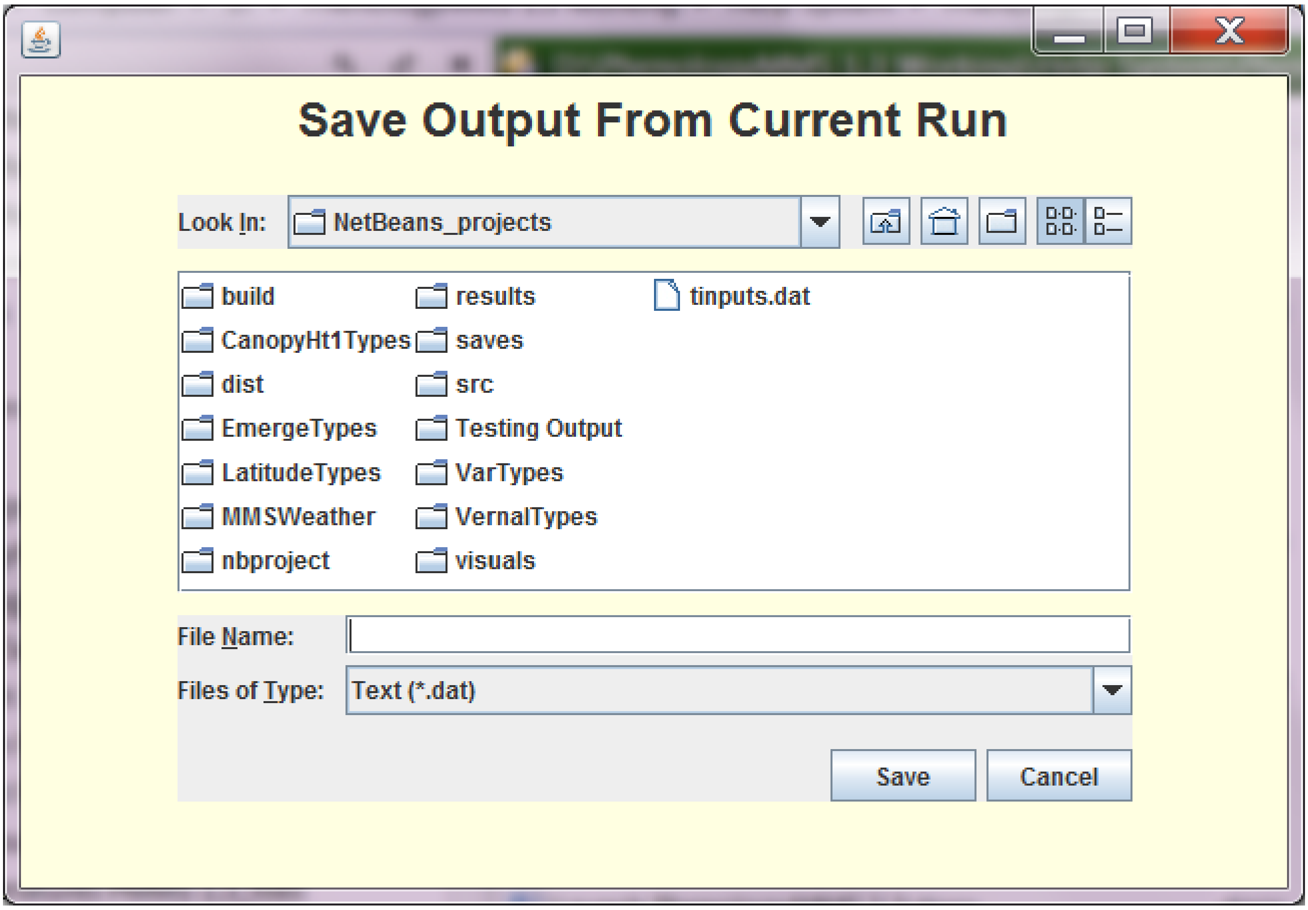
Select the Project folder you are running from to save the output with the project. From the ‘Look In:’ drop down text box, you can browse to the appropriate location. Once the location is found, choose the folder, e.g., the Results folder, in which to save the output.

The icons next to the ‘Look In:’ drop down provide other options:

- From the left-most *icon*: you can navigate up one folder , save the output file to the desktop  or create a new folder  in which to save the output.
- The two right-most icons allow you to show the display of folders as a list  or with details  such as the ‘last modified date’.

When the location is selected, give the file a name. There is only one file type available which is text with a .dat extension.

Press the ‘Save’ button to complete saving the output or press the ‘Cancel’ button to abort the operation. This screen will close when either button is pressed.



Links to: Save Current Scenario
Run PhenologyMMS 1.3

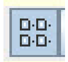
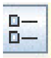
Save Current Scenario

The ‘Save Current Scenario’ screen is accessed from the ‘Save Scenario…’ button on the ‘Output From PhenologyMMS’ screen. This will save the *inputs* used to create the current *scenario*. This can then be used to re-*run* the current scenario.

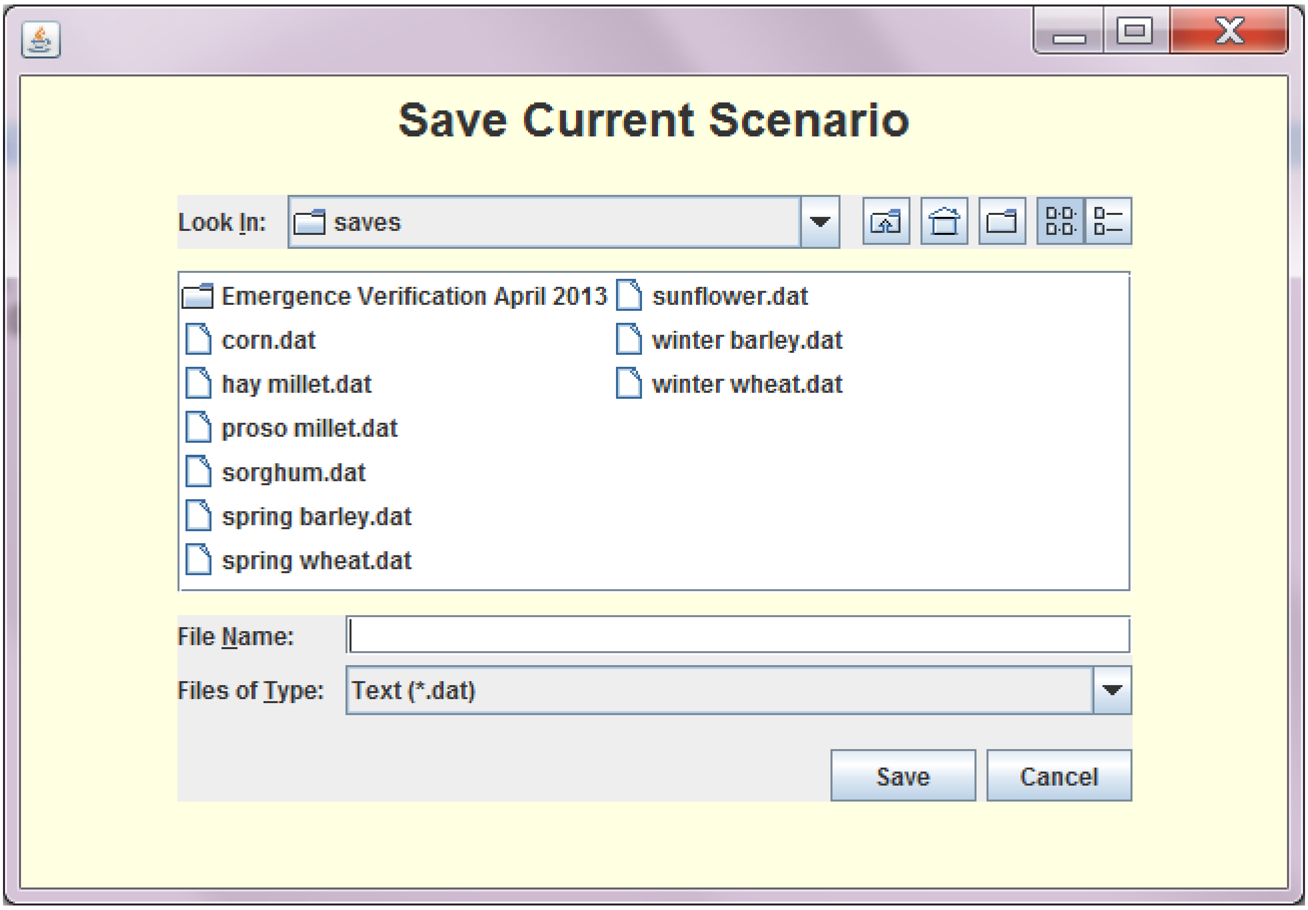
Be sure to save the file to the ‘saves’ folder as it is in this folder that PhenologyMMS 1.3 looks for the scenarios to populate the list of saved scenarios in the ‘Begin Setup’ screen drop down for the Load Saved Scenarios button.

From the ‘Look In:’ drop down text box, you can browse to the appropriate location. Once the location is found, choose the ‘saves’ folder, in which to save the scenario.

The icons next to the ‘Look In:’ drop down provide other options:

- From the left-most *icon*: you can navigate up one folder , save the output file to the desktop  or create a new folder  in which to save the output.
- The two right-most icons allow you to show the display of folders as a list  or with details  such as the ‘last modified date’.

When the location is selected in which to save the file, give the scenario file a name. There is only one file type available which is text with a .dat extension. Press the ‘Save’ button to complete the save operation or press ‘Cancel’ to stop the operation. Either of these buttons will close the screen when pressed.



Links to: [Save Current Output]
[Run PhenologyMMS 1.3]

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