PLANTEMP

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Description

PLANTEMP is a microcomputer program, based on a model developed by Agricultural Research Service scientists, that uses accumulated temperature from planting time to calculate emergence and leaf development of main stem and tillers under unstressed conditions. A graphics routine allows comparison of plant growth under two different temperature patterns. It also provides graphic display using actual temperature data from seeding and historical records to predict development.

Users

For wheat and barley growers, agricultural chemical field representatives, Natural Resources Conservation Service field staff, Extension agents, and others concerned with wheat plant development.

Authors

Ron Rickman, program developer and research scientist, Sue Waldman, programmer, and Betty Klepper, professor of plant physiology and research leader, Agricultural Research Service, USDA, Columbia Basin Agricultural Research Center; Jerry Brog, former OSU Extension agent, and Russ Karow, Extension cereal specialist, Oregon State University.

Compatibility

IBM PC or compatible with PC DOS or MS DOS, 256K random access memory, BASIC language, and IBM graphics capability.

Ordering

Order copies of PLANTEMP, EM 8308:

Publications Orders
Agricultural Communications
Oregon State University
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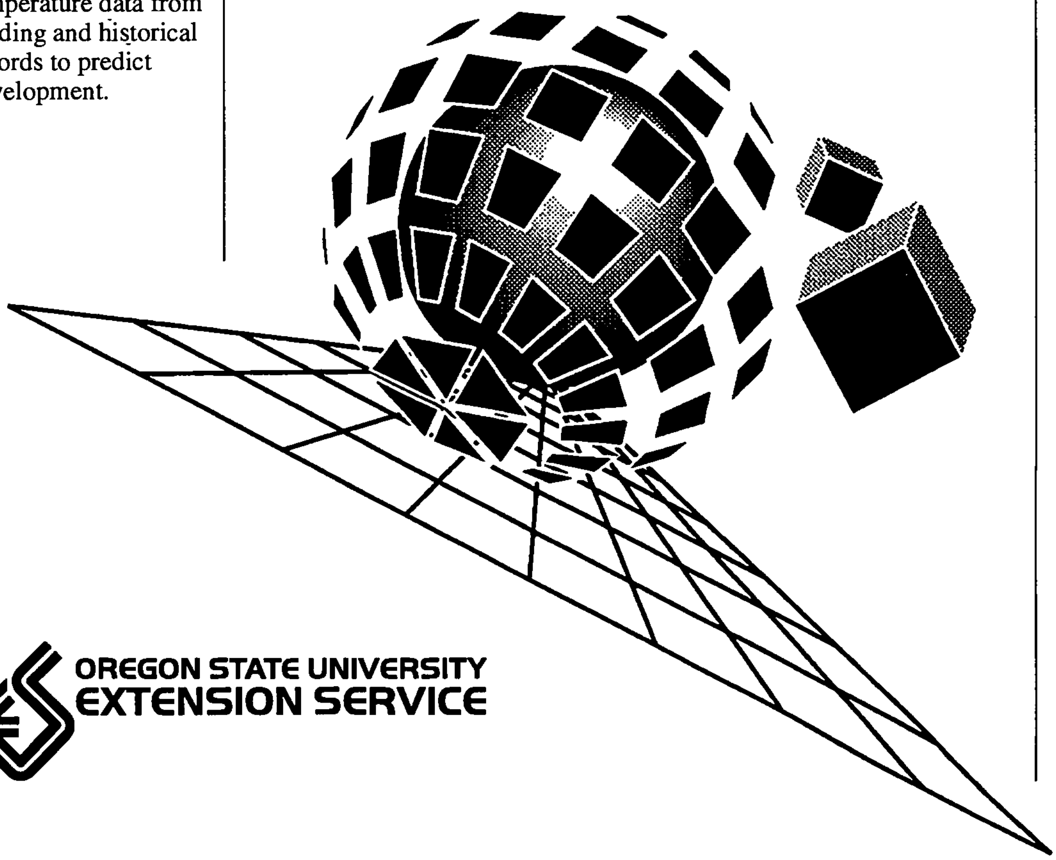
Corvallis, OR 97331-2119

Please include $25 per software package.



OREGON STATE UNIVERSITY
EXTENSION SERVICE

PLANTEMP 2.11
Reprinted August 1995

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Introduction

PLANTEMP is a micro computer program that predicts vegetative stage wheat plant development and ground cover by wheat plants. It is based on a growth model developed by USDA-ARS scientists Betty Klepper and Ron Rickman (Klepper et al., 1982) and a ground cover model developed by USDA-ARS scientists Ron Rickman and Paul Rasmussen (Rickman and Rasmussen, 1985). The program is intended for use by wheat growers, agricultural industry field staff, Extension and Soil Conservation Service employees.

The growth model is explained in Appendix A. This model uses accumulated heat units to predict emergence and leaf development of the main stem and tillers of wheat plants grown under optimal conditions. No head formation or yield estimates are made. The ground cover model is detailed in Appendix B. In addition to temperature data, row spacing, seed size, seeding rate and soil moisture information is required.

In Version 2.0 of PLANTEMP, both historical and real time temperature data had to be input by the user. Version 2.1 includes an additional option which allows use of historic weather files created for a program called WEATHERWIZARD. One such file, PENDAVE, is included on the PLANTEMP program disk as an example. A list of available files and the procedure for obtaining this information is given in Appendix C.

A graphics routine is included to allow comparison of plant growth under different temperature patterns or to display growth using actual temperature data and historical records to predict future development. A computer capable of doing graphics is required to access this portion of the program.

Systems Requirements

IBM-PC or IBM compatible computer
PC DOS or MS DOS
256 K memory

Operations Notes

All DOS operating system restrictions apply, especially the eight character limitation on file names. A **<ctrl> <break>** command sequence can be used to stop the program at any time.

This program has been compiled. Source code is available on request.

Please make a copy of your master disk. Use your copy as a working disk and keep your master in a secure place.

All data files must have a .DAT extension to be recognized by the program. Rename your data files if necessary.

Definitions

Degree days. As used in this model, degree days are calculated by adding minimum temperature to maximum temperature for each day and dividing by two, then converting this average to Celsius. Degree days are in Celsius with a zero base. For convenience, this conversion is included in the program. Data entry for temperature files is done in Fahrenheit.

Phyllochron. This is the number of degree days required for the development of one Haun growth stage.

Haun Growth Stage. The Haun growth stage measures vegetative development of wheat plants as the number of leaves visibly present on the main stem of the plant. Each fully developed leaf is one Haun growth stage (Haun, 1973).

Program Initiation

A. Make a working copy of PLANTEMP.

Format a new disk with the "format" command on your computer. Copy the PLANTEMP files to this new disk using the "copy *.*" or "diskcopy" command. Store your master PLANTEMP disk in a secure place.

B. One-drive system.

Place the working copy of PLANTEMP in drive A:, type PLANTEMP and press **<return>**. This will start the program. Data files will be stored on the working copy disk of PLANTEMP unless a B: drive designation is used and another formatted disk is used as called for file storage.

C. Two-drive system

A two drive system can be operated as a one-drive if data files will be stored on the program disk. If you wish to store files on a B: drive disk then at the A> type "B:" to make the B drive the default drive. Insert your data disk in drive B and the program disk in drive A. At the B:> type "A:PLANTEMP". The program will now run with file storage on the B drive.

D. Hard disk operation.

Create an appropriate sub-directory on your hard disk and copy the PLANTEMP program and data files to this sub-directory. To initialize the program, go to the PLANTEMP sub-directory and type PLANTEMP.

Program Operations

Once you have initiated the program the screen will show the MAIN MENU:

```
***********************************************************************************
*   --DEGREE DAY, COVER, PLANT DEVELOPMENT CALCULATOR - REVISION 2.1--   *
*          PROGRAMMED BY RON RICKMAN - USDA, ARS - PENDLETON             *
* CONTRIBUTIONS BY BETTY KLEPPER AND SUE WALDMAN - USDA, ARS - PENDLETON *
*               JERRY BROG - OSU EXTENSION - PENDLETON                   *
*               RUSS KAROW - OSU EXTENSION - CORVALLIS                   *
***********************************************************************************

              CHOOSE A MENU SELECTION NUMBER

        -1-   DATA UTILITIES

        -2-   PLANT COMPUTATIONS

        -3-   DISPLAY RESULTS AS A GRAPH

        -4-   STOP
```

Type the number corresponding to the desired function and press **<return>**.

Data Utilities Menu

Typing 1 followed by **<return>** will activate the following submenu:

```
                    DATA FILE UTILITY MENU

                CHOOSE A MENU SELECTION NUMBER

   -1-    ENTER NEW TEMPERATURE DATA FILE

   -2-    ADD TEMPERATURES TO AN EXISTING FILE

   -3-    COMBINE TWO FILES INTO ONE

   -4-    EXAMINE TEMPERATURES AND CALCULATED VALUES

   -5-    LIST DISKETTE DIRECTORY

   -6-    CONVERT LONG-TERM AVERAGE FILES TO PLANTEMP FORMAT

   -7-    CONVERT ANY DATA FILE TO PLANTEMP FORMAT

   -8-    CONVERT FILE FROM PLANTEMP 2.0 FORMAT TO PLANTEMP 2.1 FORMAT

   -9-    RETURN TO MAIN MENU
```

Selection 1. Enter New Temperature Data File

In order to use this program for your specific situation you must create a temperature file. Select number **1** and **<return>**. You will be asked to name the file (conventional naming limitations apply, i.e. no more than eight characters. We suggest a location and date be used in the name. For example PEN89-90 for Pendleton location and the 1989-90 growing season).

After typing the name and **<return>**, the screen will show the files on the disk and ask if the name is O.K. to use. If a name is the same as a file already on the disk, the old file will be destroyed. Type **Y** if it is O.K. to use the name as entered or **N** if it is not and then

<return>. Follow the on-screen prompts to create the file by entering Fahrenheit temperatures. If you type in a minimum temperature greater than your maximum, you will be asked to re-enter the values. You can correct a mistake while entering a file by typing **B**, instead of a temperature value, to back through the file one day at a time. Type **E** to end input.

Once a file is created, it can be edited using the procedure outlined on screen. Type the row number (far left column) of the date that needs to be corrected and then the column number at the on-screen prompt. Follow instructions to make corrections. Press return to review data screen by screen. Type S **<return>** to skip a specified number of days. Type **E** to end the edit function. When you are finished, you are offered one last chance to review the new file. A **N** response at this final query returns you to the main menu.

Selection 2. Add Temperatures to an existing file

You will be asked for the file you want to use. The last file entered is the default file. Other data files on the disk will be displayed. Press return to use the indicated default file or type in the name of another file you have previously created. The screen will show the data from the file and on-screen instructions for corrections to data already entered or for entering additional data. Type **E**, instead of a value, to end input. You will be asked if you want to review data. A **N** response returns you to the main menu.

Selection 3. Combine two files into one

This allows you to combine two files of your choice. Designate the two files at the screen prompt. When these files are loaded, you will be asked to name the new combined file. Names of data files already on the disk will be displayed. This routine adds data from one file to another. Data from the second file will be added to the bottom of the first. Error messages will be displayed such as overlapping dates, gaps in data, etc. Overlapping dates will be deleted *from the second* file.

Selection 4. Examine temperatures and calculated values

As in Selection 2 or 3, you will be asked for the temperature data file you wish to use. After the file is loaded, the screen will show start and end dates for the file and ask for a planting date. The planting date must fall within the confines of the dates in the file. You are then asked for the date you would like as a prediction date. The default value is the last day in the file. Press **<return>** to use this date. If you would like an earlier date (the prediction date must be within the date limits of the file) enter the desired month and date at the on-screen prompts.

Summed degree days (DDSUM) will begin to accumulate on the planting date you selected, *but will be displayed from the first day of the file.*

The screen will look as follows:

114 RECORDS IN -- CDDSUM IN CELSIUS

ROW	YR	DOY	MON	DAY	MAX-TEMP	MIN-TEMP	DDSUM	HAUN
COLUMNS—	1	2	3	4	5	6	7	8
1	89	258	9	15	67	39	0	0
2	89	259	9	16	68	35	10	0
3	89	260	9	17	66	40	22	0
4	89	261	9	18	68	39	34	0

ENTER ROW NUMBER to correct, S to skip rows, E to end, return for next screen

Identification of the columns in the file display screen:

ROW	The row number in your information
YR	Year for the information in that row
DOY	Day of the year from January 1 (Julian date)
MON	Month
DAY	Day of the month for the row
MAX-TEMP	Maximum temperature in F for that day
MIN-TEMP	Minimum temperature in F for that day
DDSUM	The accumulated degree days in Celsius from your selected planting date
HAUN	The expected Haun growth stage

Corrections or a review of the total file may be exercised at this time. Typing E and <**return**> will take you back to the utilities menu.

Selection 5. List diskette directory

This shows the directory of the disk in the default drive.

Selection 6. Convert long term average files to PLANTEMP formal

This selection converts long-term average weather files created for use with another computer program called WEATHERWIZARD to PLANTEMP compatible files. The WEATHERWIZARD file for Pendleton, Oregon (PENDAVE.DAT) is included on the PLANTEMP disk for your use in trying this program selection.

After selecting this option, the program will ask you for the name of the long-term file to convert. A list of available files will be displayed on-screen. Enter the name of the file. You will then be asked for the earliest planting date to be used with this file. The default date is August 1 (8/1). You can specify other dates by entering the month and date as prompted. If you wish to keep your data files in calendar order, specify January 1 (1/1) as the starting date.

The program will then convert the file and ask you for a new file name. The list of current files will still be displayed at the top of your screen. Check the list carefully as there is no fail-safe at this point in the program to prevent you from over writing an existing file. Once you have entered the file name, you will be returned to the Utilities menu. You now have access to the converted file for use elsewhere in the program.

Selection 7. Convert any data file to PLANTEMP format

This selection converts ASCII data files containing date and weather data in column format to PLANTEMP format. The file to be converted must have a .DAT extension (rename yours if necessary) and an end of file mark or a - 999 at it's end. The program will ask for the name of the data file to convert, for the number of columns in the file and the column location of year, day of year, month, day, maximum temperature, minimum temperature and units for temperature data (F or C). You will be asked to provide a new file name. If one of the requested data items is not present in the file to be converted, simply enter the default value 0 at the on-screen prompt. PLANTEMP will calculate day of year if month and day are given. Year and minimum and maximum temperature values can not be calculated. Missing values can be added using the edit function in Selection 2.

Selection 8. Convert file from PLANTEMP 2.0 format to PLANTEMP 2.1 format

This function allows conversion of files you may have created using the first version of PLANTEMP. Enter old and new file names at the on-screen prompts.

Selection 9. Return to main menu

Plant Computations Menu

The Plant Computations submenu follows:

```
PLANT COMPUTATIONS MENU

CHOOSE A MENU SELECTION NUMBER

-1-   PLANT DEVELOPMENT

-2-   PLANT COVER

-3-   CHANGE EMERGENCE OR PHYLLOCHRON LENGTH

-4-   EXAMINE TEMPERATURES AND CALCULATED VALUES

-5-   RETURN TO MAIN MENU
```

Selection 1. Plant development

This selection utilizes a real time data file for current season temperatures and temperatures in a historical average file to predict plant development at a date you specify. You will be asked to identify the real time file , a historic file, and a planting date. The program defaults to HISTAVG, a historical average file, if **<return>** is pressed. The HISTAVG name should be used for historic temperature data appropriate for your area. A sample file with that name already exists on the disk. This will be replaced when you create and save your own HISTAVG file to the disk. A historical file appropriate for your area can be obtained (see Appendix C) or you may make one of the historic files provided on the program disk your HISTAVG file. Historic files for Pendleton (HISTPEND.DAT) Moro (HISTMORO.DAT) and Baker (HISTBAKE.DAT) are provided on disk.

After you enter a planting date, you will be asked for a first prediction date. The default date for prediction is the last day in the real time data file. You can default to this date, specify an earlier date or enter a later date. If you default, the first prediction given will be for the last date for which real time data is available. If you specify a date beyond the confines of the real time data file, the first prediction **will still be for the last date in the real time file**. If you specify an earlier date, the first prediction will be for that earlier date. In all cases, the first prediction shown will be a prediction using real time data. It is easiest to default at this point.

After entering the first prediction date, you will be asked for a current prediction date. This is generally a date beyond the last day for which real time temperature data is available. This prediction requires the use of the specified historical data file. Enter a month and date as prompted. The current prediction will appear on the right half of your screen (see below).

AS OF 1/4/90 729 GDD SINCE 9/15/89		AS OF 2/1/ 760 GDD SINCE 9/15/89	
TILLER	LEAVES	TILLER	LEAVES
MS	6.1	MS	6.4
T0	3.3	T0	3.6
T1	3.0	T1	3.3
T2	2.3	T2	2.6
T3	1.3	T3	1.6
T10	1.2	T10	1.5
T4	0.3	T4	0.6
T20	0.5	T20	0.8
T11	0.3	T11	0.6
T5	0.3	T5	0.6
		T100	0.3
T01	0.3	T01	0.6

Pressing <**return**> will take you back to the plant computations menu.

Selection 2. Plant cover

This sub routine uses the same information as Selection 1 (Plant Development) but also asks for the following additional information: seeding rate in pounds per acre, kernels per pound, row spacing, approximate percent germination, and type of site (wet or dry). The resulting display shows plants per square foot, growing degree days, ground cover in percent and plant development for the two selected prediction dates. A sample printout is shown below.

PLANTING	= 100 LBS/ACRE	KERNELS/LB	= 10000
DRILL ROW SPACING	=12 IN.	PERCENT GERMINATION	= 80

18.5 PLANTS/FOOT

COVER PREDICTION FOR A WET SITE - MORE THAN 15 IN. RAIN/YR

AS OF 1/4/90	AS OF 2/1/
729 GDD SINCE 9/15/89	760 GDD SINCE 9/15/89
41 % COVER	44% COVER PREDICTED

<return> to display Plant Development

?

Selection 3. Change Emergence or phyllochron length

This subroutine allows modification of the parameters used in computations. Changeable parameters include:

Emergence requirement	Number of degree days between planting and emergence (default is 150)
Phyllochron	The number of degree days required for one leaf to develop (default is 95)
Leaf length	This is used in cover computations (varies with leaf number)
Number of plants required to provide 100% cover	This is used in cover crop computations (default is 15)
Amount of mutual shading	This is used in cover computations (default is 1)

<return> after response to mutual shading takes you back to the Plant Computation menu.

Selection 4. Examine temperatures in calculated values

This selection is identical to Selection 4 in the data file utilities section.

Selection 5. Return to main menu

Display Results as a Graph

This menu utilizes graphics to visually compare plant development or cover. Your computer must be graphics capable in order to use this menu. Selections are as follows:

```
                    PLOTTING MENU

        CHOOSE A MENU SELECTION NUMBER

  -1-   COMPARE TWO FILES

  -2-   DISPLAY PREDICTED DEVELOPMENT

  -3-   RETURN TO MAIN MENU
```

Selection 1. Compare two files

This selection allows you to compare temperature data in any two files. You are prompted to supply the two file names. You will be asked to select one of the following parameters as the data to be shown on the X and Y axes.

Day of the year

Maximum temperature

Minimum temperature

Degree day sum

Haun value

You will be asked to enter starting and ending values for the X and then the Y axis. Extremes within the data set for each axis will be shown on-screen. Select scale values for each axis which are outside of these extremes.

Premarked intervals on the graph are 5 on the Y axis and 10 on the X axis. You may want to use values easily divisible by these numbers to conveniently read the scale. The program does not label intermediate points on the scale.

Selection 2. Display predicted development

This selection operates like Selection 1 (Plant Development) of the plant computation menu, but output is graphic. This selection also asks for a real time file and a predictor file. A planting date is selected from the real time file and a date for desired development or cover is selected from the predictor file.

The variables available for each axis are the same as Selection 1 (Compare Two Files). You will also need to identify starting and ending values for each axis.

The plot shown on the screen will identify the end of your temperature file with an X. The remaining plot is from the predictor file.

Selection 3. Return to main menu

Stop

Choose number 4 on the main menu to exit to DOS.

References

Bauer, A., A.B. Frank, and A.L. Black. 1984. Estimation of spring wheat leaf growth rates and anthesis from air temperature. Agron. J. 76:829-835.

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Klepper, E., R.W. Rickman, and C.M. Peterson. 1982. Quantitative characterization of vegetative development in small cereal grains. Agron. J. 74:789-792.

Rickman, R.W. and Paul E. Rasmussen. 1985. Ground cover estimates for seedling cereal crops. Soil Science Society of America Journal 49:1251-1255.

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Appendix A. Wheat Plant Development Model

Tillers, leaves, and roots of winter wheat:

Using expected development patterns to compare field grown plants.

R.W. Rickman and Betty Klepper[1]

Introduction

The consequence of various dryland farming management choices can be found by their impact on wheat plant development. Leaf and tiller development of the wheat plant follow a rigidly regular development pattern in excellent growing conditions. Recognizing this pattern and comparing it to actual development of a plant provides one of the best methods for evaluating the quality of growing conditions in a wheat field. Proper evaluation of environmental or management effects requires that a person be able to identify the various leaves, tillers, and roots of a plant. Identification is easiest if the leaves of the main stem of the plant and the nodes which form them are used as the major indicator for all of the tillers and roots. The following information explains how the various parts of the plant, particularly those on the main stem, are identified and how they are interrelated.

Leaf, Tiller, and Root Naming System--Nodes of the Plant

To describe a wheat plant, we number each leaf, tiller, and root with the number of the node from which it forms (Figure 1). The first node in the crown (Node 1) bears the first leaf (L1) and the first tiller (T1) as well as the roots associated with this node (1A, 1B, 1X, 1Y). the successive leaves of wheat are produced on alternate sides of the stem so the base of the second leaf (L2) is immediately above Node 1 on the opposite side of the stem from L. The main stem nodes are numbered successively up the stem beginning at the bottom of the crown where Node 1 is normally found. Below the crown are three more nodes. The coleoptilar node, located just below Node 1, is given the number "0" and the two nodes below it are given negative numbers (-1, -2). These negative numbered nodes are present in the seed and produce the seminal roots.

The nodes which form the crown of a wheat plant (usually nodes 1 through 6) all are produced after the plant has germinated.

---

[1] Soil scientist and plant physiologist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

Tiller leaves, roots, and subtillers also develop from nodes which make up the tiller itself. Two digit numbers identify tiller nodes (10, 11, 20, ...) and three digit numbers are used for subtillers (100, 101, ...).

Shoot Development Pattern

The leaves on the main shoot (MS) of wheat elongate successively with the same amount of "biological time" (same number of degree-days) being required for elongation of each leaf. The main shoot is the stack of nodes -2, -1, 0, 1, 1.... through the node which produces the flag leaf. As the fourth leaf (L4) elongates, T1 appears in unstressed plants (Figure 2). This tiller continues to develop in lock-step with the MS once it begins so the number of leaves on T1 and on the MS always will remain offset by about three. For example, an unstressed wheat plant with 5.2 leaves on the MS will have a little more than two leaves on its T. The general scheme presented in Figure 2 applies to all varieties of wheat, both winter and spring, both red and white. The steps of biological time represented by the small breaks in the vertical lines in the figure are called phyllochrons. A phyllochron is the length of biological time it takes for a leaf to elongate. For example, it is the length of time of the amount of heat it takes to go from a main stem leaf number of 4.2 to one of 5.2.

This same pattern of leaf and tiller development is presented in the lower right one-half of Figure 3. To find the number of leaves and tillers on a plant with Figure 3, a vertical line that we call an age line is drawn upward from the bottom of the figure. Age is measured here by the number of leaves on a main stem or tiller. For example, an age line from five phyllochrons after emergence in Figure 3 intersects the sloping lines representing T3, T2, T1, T0, and main stem. An unstressed plant five phyllochrons old will have each of these tillers formed. A horizontal line or a straight edge placed across the figure from left to right where the age line hits a tiller line will permit reading the number of leaves on that tiller from the right side of the figure. With the age line at five phyllochrons, the main stem will have five leaves, T0 will have 3.2 leaves, T1 will have 2.5 leaves, and so on.

Root Appearance with Respect to Shoot Development

Two pairs of four roots may form from each node. Each node may be divided into four equal-sized pie-shaped sections or quadrants labeled in clockwise order from the tiller as X, A, Y, and B. One root will usually form from each section. Crowding from older roots, tillers, or twisted main stem development can make the exact points of origin of roots with a node unsymmetrical.

The seminal roots come from the two nodes (1-2 and -1) that are present in the seed. The -2A and -2B roots elongate almost immediately after the radicle and only after these three roots have elongated does the coleoptile show significant growth. The coleoptile depends on water taken up by these three roots for emergence. After emergence, the A and B roots at the -1 node elongate. In addition, another seminal root often appears at the -1 node in especially vigorous seedlings. Thus, there can be up to six seminal roots on a normal wheat plant.

The sequence of root appearance at main stem nodes relative to plant phyllochrons is diagrammed in the upper left half of Figure 3. The vertical lines are labeled with names of pairs or roots. The expected time of appearance of each pair can be read (in terms of phyllochrons after emergence) across the top of the figure. Notice at the Radicle and Node -2 roots begin elongating about one phyllochron before emergence.

The crown root system (which forms from Nodes 2 to 5 or 6) begins to develop when tillering begins. A pair of roots (one in each of the A and B quadrants) appears at about the same time that the tiller is produced at that node. About two phyllochrons later, a second pair (one in each of the X and Y quadrants) may elongate, especially if there is a tiller at the node.

Figure 3 summarizes the relationship between shoot and root development and root branching as well. A horizontal line across Figure 3 at the number of leaves on the main stem of the plant will cross each root pair line showing the branching expected on those roots. For example, a plant with 5.5 leaves on the MS has secondary branching on seminal roots (Radicle, -2 and -1 nodes), but the crown roots (nodes 1 and above) just have beginning first-order branches or are unbranched. The individual tillers begin to form roots at their own nodes when the tiller has three leaves. Figure 4 illustrates the relative number of leaves, number of roots, and relative length of roots that are on an unstressed plant just before boot stage.

Effect of Stress on Plant Development Patterns

Stresses are detected in a wheat crop by observing a population of plants rather than only one plant. Table 2 provides a comparison of observations on plants from severely compacted and uncompacted sites in a field. Many more of the plants in a compacted soil skipped some or all their tillers. If 100 plants had been observed from each soil condition, none of the plants from compacted soil developed T0 while 79 from uncompacted soil developed T0. Similar comparisons apply to all the other tillers.

Since each tiller on a plant will only appear during a brief "window" of time (within ½ phyllochron or less of the time scheduled on either Figure 2 or 3) missing tillers show not only stress, but when the stress occurred. From Table 2, for example, plants from compacted soil experienced a major stress during the second phyllochron (the time when T0 was expected -- see Figure 2 or 3). During phyllochrons 3 through 5, compacted plants produced only 75 to 80 percent of the number of T1's, T2's, or T3's as plants in uncompacted soil. This indicates a prolonged consistent difference in the growing environment between the two treatments. Roots at the X and Y nodes may also be skipped and although A or B roots are rarely skipped, they will be weak if the tiller at their node does not form or aborts after beginning.

Biological Time or Growing-Degree Days

The measurement of "biological time" under field conditions is by the use of cumulative growing-degree-days (GDD) with a zero centigrade base temperature. The use of GDD for predicting and comparing wheat development under field conditions was discussed in the 1983 Columbia Basin Agricultural Research, Special Report 680. To calculate base zero GDD's follow these steps:

1. Obtain daily maximum and minimum Fahrenheit temperatures from planting to the present for a location close to the field you are interested in.
2. Calculate the average Fahrenheit temperature each day from

$$\frac{\text{Max} + \text{Min}}{2}$$

3. Convert this average temperature from Fahrenheit (F) to centigrade (C) degrees with this Formula:

$$C = \frac{5\,(F-32)}{9}$$

4. Since the base temperature of zero C applies to wheat, all average temperatures below zero are changed to zero.
5. Add together all of the values from planting to the present to obtain the cumulative GDD's for the crop. Table 1 shows an example of this calculation.

Be sure not to mix computations and growth estimates from GDD's calculated using different base temperatures or directly with Fahrenheit temperatures.

Under most Pacific Northwest winter wheat planting conditions, it takes from 130 to 150 base zero GDD's for the emergence and 90 to 100 base zero GDD's for each leaf to elongate. For example, if 500 GDD's had passed since planting, one would expect to find a little more than 3.5 leaves on a winter wheat crop. These plants probably would have tillers at the "0" and at the"1" node (Figure 2 or 3).

Summary

The orderly developmental pattern of wheat shoots and roots can be predicted using growing-degree-days to time development. With stress, tillers and roots fail to elongate and the leaves on those culms already present elongate but are smaller than normal. The stress history of a crop can be "read" from the sizes and relative development of the leaves, tillers, and roots. The timing of stress in actual days is done by the relationship between GDD and days in your weather records.

FIGURES

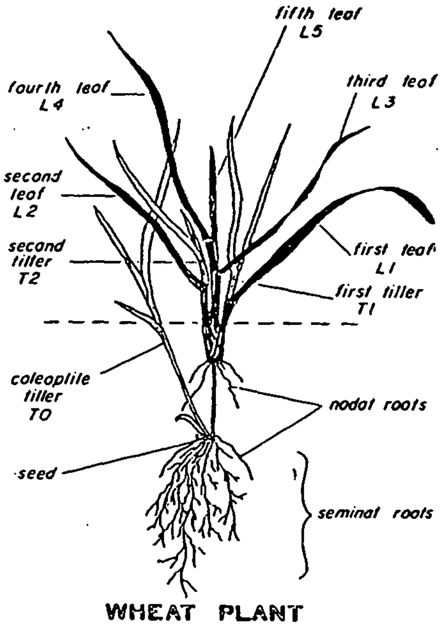

Figure 1. Winter wheat plant with labeled leaves, tillers, and roots.

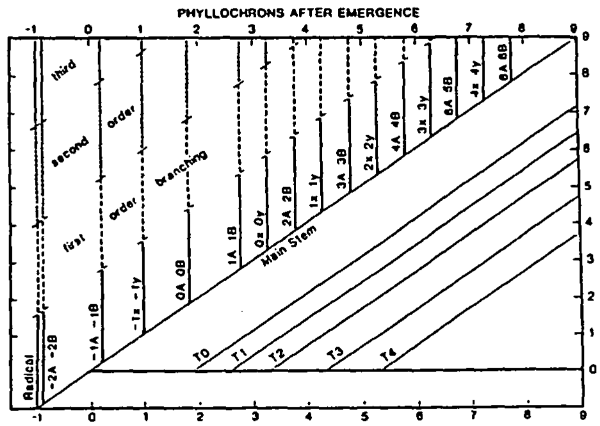

Figure 3. Diagram of leaf, tiller, and root development pattern for wheat.

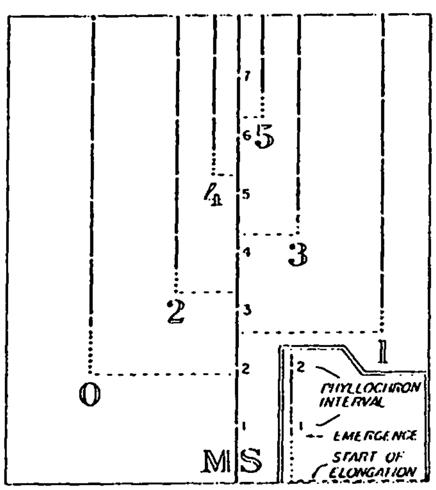

Figure 2. Diagram of leaf and tiller development pattern for wheat.

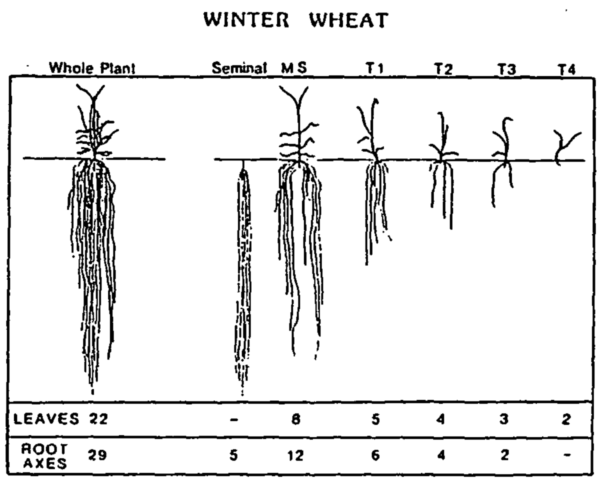

Figure 4. Relative sizes of the tillers, leaves, and roots of a wheat plant just before boot stage.

Table 1. - Cumulative growing-degree-days example. The max, min temperatures represent 8 a.m. readings as done on most experiment stations. The temperatures reported for Monday are for the 24 hours from 8 a.m. Sunday to 8 a.m. Monday.

Day	Max	Min	Ave (°F)	Ave (°C)	Cumulative degree-days
Monday	52	40	46.0	7.8	7.8
Tuesday	55	38	46.5	8.1	15.9
Wednesday	49	37	43.0	6.1	22.0
Thursday	56	34	45.0	7.2	29.2

Table 2. - Percent of winter wheat plants with identified tillers present in compacted and uncompacted soil.

	Tillers present (%)				
Treatment	T0	T1	T2	T3	T4
Compacted soil	0	74	82	69	28
Uncompacted soil	79	97	100	93	90

Appendix B. Wheat Plant Ground Cover Model

Ground Cover by a Winter Wheat Crop

R.W. Rickman and Paul E. Rasmussen[1]

An overwinter 50 percent ground cover is sought as a minimum for reducing erosion in winter wheat fields. Amount of cover created before December 1 by wheat seedlings is used by the USDA Soil Conservation Service to judge the adequacy of fall management practices. Latest possible planting dates to establish minimal cover are listed for different areas but these dates are, of necessity, for relatively large areas. Using the relationship between plant leaf development and degree-days from planting, cover on December 1 can be estimated for any planting date for a specific area where long-term average daily temperatures are available. The purpose of this investigation was to determine the effect of row spacing, seeding rate, and planting date on the development of plant cover in any winter wheat field.

PROCEDURES

Assumptions

The circular area of soil surface potentially shaded by a seedling cereal plant has a radius determined by a vertical projection from the tip of the longest leaf on the plant. This vertical projection is used because the application of the computation is to estimate the fraction of the soil surface protected from raindrop impact. Any one plant shades only a fraction of that circular area because of both long narrow leaf shape and upright leaf position. If one makes five simplifying assumptions about the way shading by individual and overlapping plants takes place, the fraction of solid surface covered (shaded) by a cereal crop can be estimated. The five assumptions are: (1) leaves are positioned on the average at a 45° angle from the soil surface, (2) within the circular area of soil partially shaded by a single plant four to ten percent of the surface is shaded, (3) equidistant plant spacing within the row, (4) the shading within a circle can be represented as uniform throughout, and (5) the percent of surface shaded where adjacent plants overlap will be a sum of the shading from each plant. Equations must be provided to produce the following information:

1. Circular soil area partially shaded by a plant as a function of leaf length.
2. Area of overlap of the circular areas surrounding adjacent plants.

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3. Fraction of total soil area shaded in the circular area surrounding plants in a row.

Development of formulas

The radius (r) of the circular area potentially shaded by each plant is calculated assuming the plant leaves of length (L) are held at 45° from horizontal. Specific cultivars may vary from this value but it can be changed if required. The number of overlapping circles (n) is the truncated integer value [int ()] of the ratio of shaded area diameter (2r) to average planting spacing (X) within a row. If n is less than 1, the plants do not overlap.

$$r = L \cos(45)$$ (1) Radius for partly shaded circle around a plant

$$n = \mathrm{int}(2r/X)$$ (2) Number of overlaps of adjacent circles

The area that is common to, or overlapped by i different plants within any one circle, is calculated by C(i). The area C(1) is a complete circle. Examples of C(2) and C(3) are illustrated as shaded areas in Figure 1, row A.

$$C(i) = 2\left\{\frac{\pi r^2}{2} - \left[\frac{(i-1)X}{2} r^2 - \frac{((i-1)X)^2}{4} + r^2 \sin^{-1}\frac{((i-1)X)}{2r}\right]\right\}$$ (3) Common overlap area

In the rectangular area X by s, (where s is row spacing), the area with i circles overlapping is calculated by A(i) (Fig. 1, row B).

$$A(1) = C(1) - 2C(2) + C(3)$$ (4)

$$A(i) = C(i) - 2C(i+1) + C(i+2)$$ (5)

$$A(n-2) = C(n-2) - 2C(n-1) + c(n)$$ (6) overlap area per plant

$$A(n-1) = C(n-1) - 2C(n)$$ (7)

$$A(n) = C(n)$$ (9)

The maximum number of overlapping circles is n. Each area A(i) is shaded by i circles, or one can imagine, i layers of plants. Based on cover measurements of isolated individual plants, a plant shades four to seven percent of the circular area it occupies. The number of plants that must overlap to provide complete cover (F) ranges from 25 to 15. Shaded surface area (R(i)) in each A(i) is calculated by:

$$R(i) = A(i)\, i/F$$ (9) Shaded area in overlaps

Fractional cover for a crop is calculated as:

$$K = \sum_{i=1}^{n} R(i)/(X s) \qquad \text{(10) Fractional crop cover}$$

The fraction of the soil surface not shaded will be 1-K.

Plant development

To use equation 10 to project ground cover, methods for estimating the length of leaves on the plant and the time of development of each leaf must be available. Development of each leaf of the main stem of a plant can be linearly related to degree-days accumulated from planting or emergence (Rickman and Klepper, 1983; Bauer et al., 1984; Hay and Wilson, 1982). Emergence occurs in 90 to 150 degree-days after planting and each leaf develops in 75 to 120 degree-days depending on cultivar and planting date (Hay and Wilson, 1982). Leaf length can be obtained from observations of lengths of specific leaves from previous crops (Figure 2).

With historic air temperature records for a location to provide degree-day accumulation curves such as Figure 3, ground cover at any time after planting can be calculated for various planting dates. Ground cover measurements for comparison were taken from vertical photographs of a 1 m square with sides aligned with plant rows. Ten lines were drawn across the photographs perpendicular to plant rows within the 1 m square. The fraction of the length of all lines covering plant leaves was used as the fraction of the soil surface covered.

RESULTS AND DISCUSSION

Comparison of measured and computed cover as affected by row spacing, plant stage, and plant growth stage is shown in Table 1. The linear regression between measured and computed cover had an r^2 of .94 and a slope equal to 1.0, indicating that computed values are good estimates of actual cover.

Row spacing and seeding rate effect on cover are illustrated in Figures 4A, 4B, and 5. A seeding rate of 60 lb/A, 40 milligram seed size (11350 seeds/pound), 90 percent emergence, 120 GDD for emergence, and 90 GDD per leaf was used in Figures 4A and 4B. row spacing appears to have little effect on total percent cover (Figure 4A). However a better perspective on the effect on changing row spacing with seeding rate held constant is shown in Figure 4B. In 14-inch rows, plants are crowded together and provide relatively heavy cover in the rows, but leave much of the soil surface between the rows without shading. In the 7-inch rows, the interrow closes in much faster, although the percent cover within a plant row will be considerable less than in the wider row spacing. Figure 5 is for 10-inch row spacing with everything else except seeding rate the same as in Figures 4A and 4B. These figures could be used to estimate ground cover for different planting dates at a location. For example, an October 1 planting date at the Pendleton Airport accumulates 450 degree days by December 1 (Figure 1B). Calculated cover for December 1 for a 60 lb/A seeding in 10-inch rows would be 20 to 25 percent (solid line, Figure 5). Increasing the seeding rate to 80 lb/A would increase expected cover 25 to 30 percent (dashed line, Figure 5). A row spacing change would not change total cover (Figure 4A) but a 7-inch row spacing would leave only 10 percent of the area between rows without plant cover compared to 60 percent for the 14 inch row spacing (Figure 4B).

The calculations depend on specific leaf sizes for the variety grown. The computations developed are for Stephens. When projecting for varieties with different leaf sizes, such as the Hyslop, the calculations do not match as well. Further data on leaf sizes for specific varieties at different locations are being collected this year with more field cover observations. The computations are being incorporated into a computer program that will be available through OSU Extension.

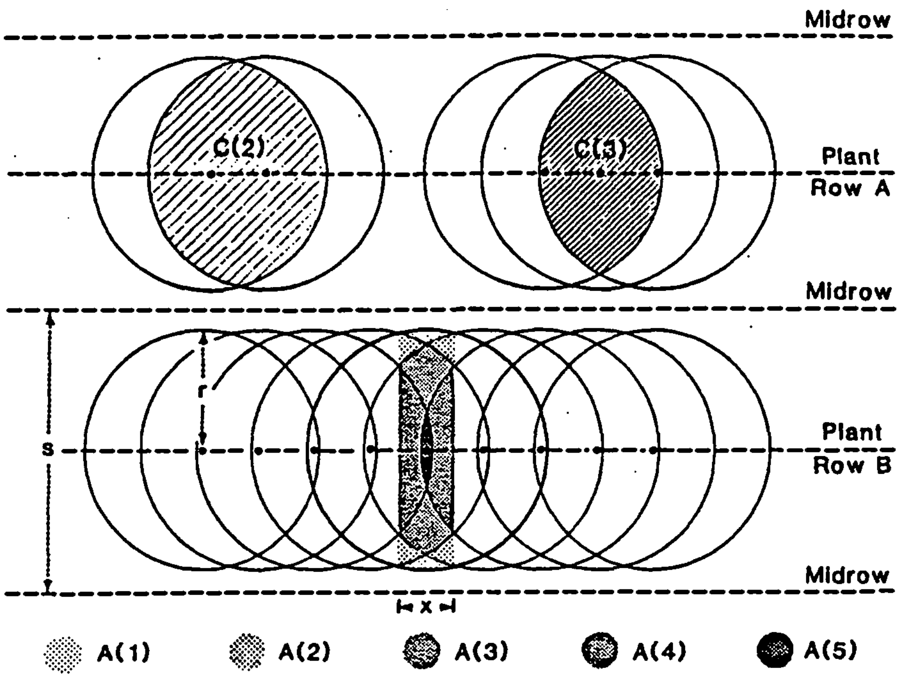

Figure 1. Overlapping areas of possible shading by adjacent wheat plants. Letter symbols illustrate variables utilized in equations listed in the text.

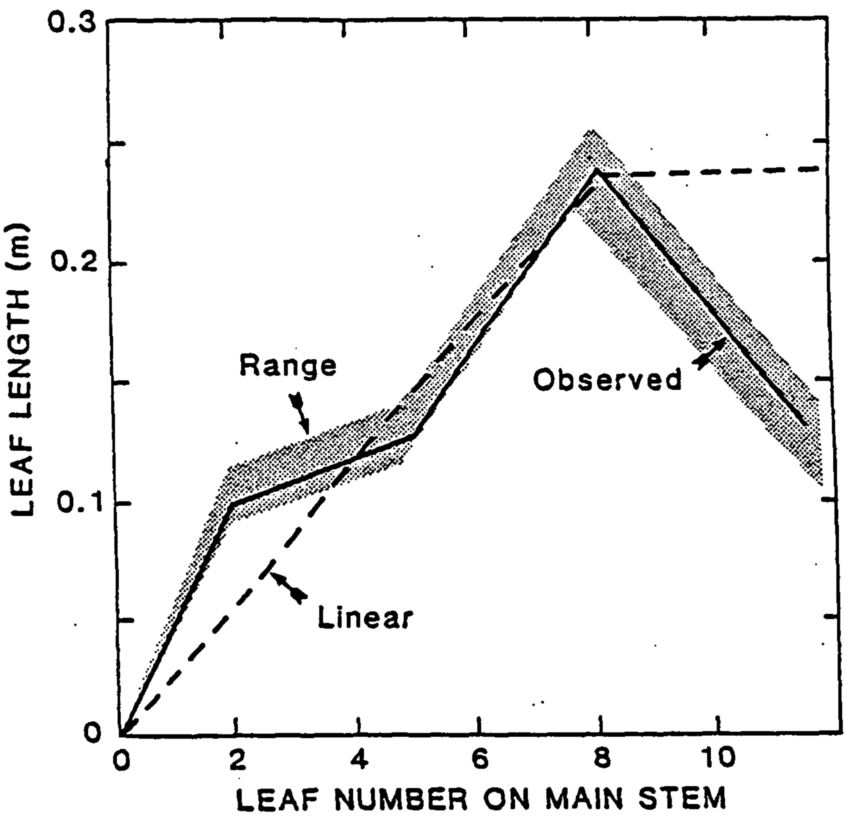

Figure 2. Leaf length vs leaf number for fertilizer timing treatments on Stephens winter wheat near Pendleton, OR. in 1982. Dashed line represents a hypothetical linear increase in leaf length with leaf number.

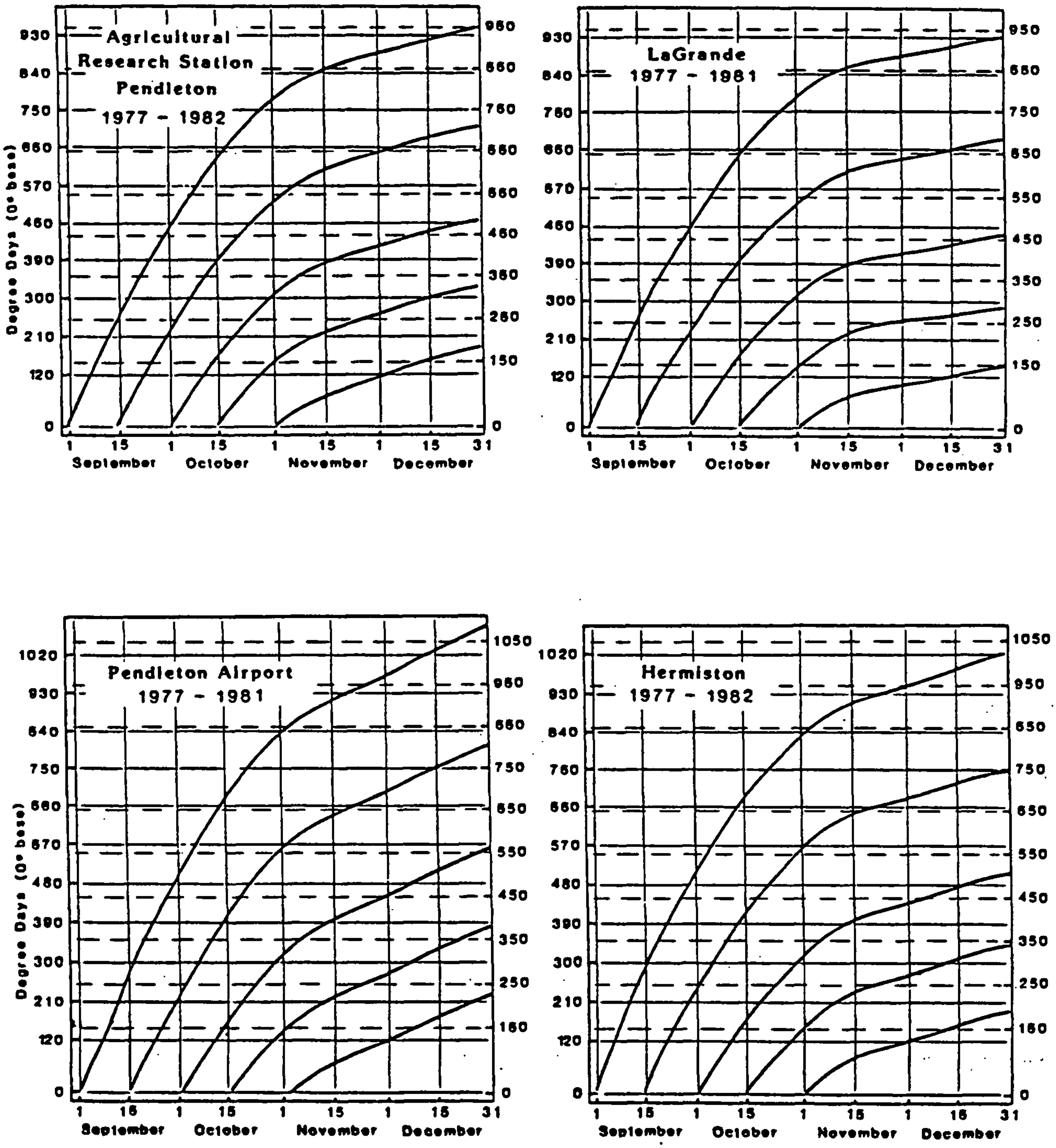

Figure 3. Expected accumulation of growing degree days from the first and fifteenth of the month during the fall planting season for four locations.

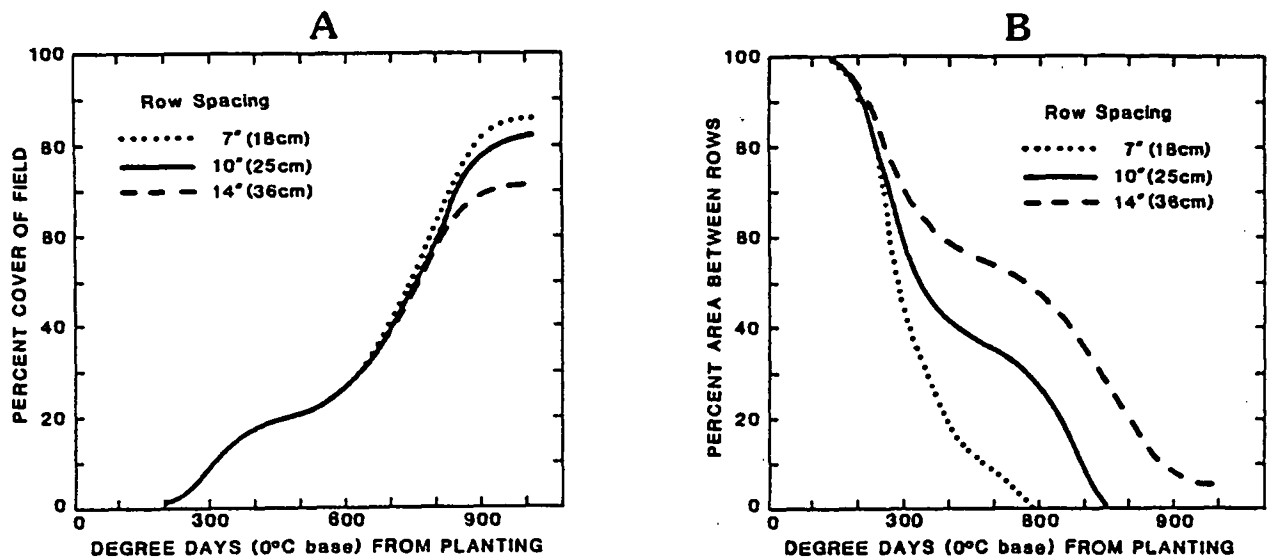

Figure 4. (A) calculated plant cover development for three different row spacings.
(B) calculated bare between row area for three different row spacings.

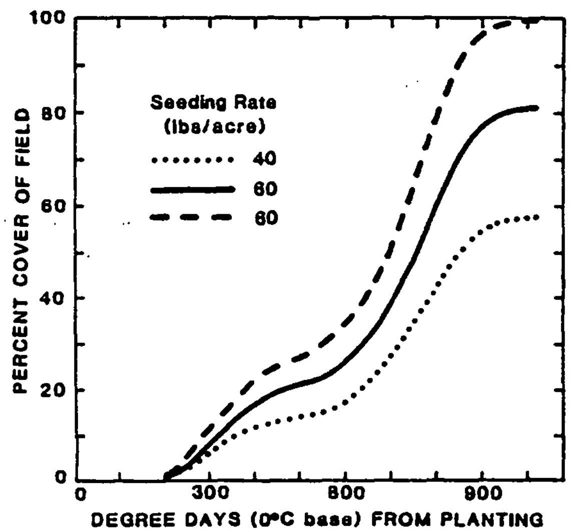

Figure 5. Calculated plant cover development for three different seeding rates.

Table 1. Observed and calculated ground cover for Hyslop (1977) and Stephens (1981, 1984) winter wheat as affected by stand density, row spacing, and growth stage

Stand	Row spacing	Main stem growth stage	Total ground cover observed	Total ground cover calculated
plants/yard	inches	no. of leaves	%	%
1977				
59	14	4.2	18	10
59	14	5.8	23	19
59	14	6.9	23	37
25	14	4.3	8	5
25	14	6.0	13	9
25	14	7.0	19	18
1981				
7	7	3.3	3	4
15	7	3.4	6	9
30	14	3.4	5	4
7	7	4.5	9	6
15	7	4.5	14	12
30	14	4.6	13	6
1984				
23	10	1.5	3	1
23	10	3.1	8	6
23	10	4.9	12	10
23	10	6.9	32	30
23	10	10.5	60	51

Appendix C. Long-Term Weather Records

Long-term (30 year average) weather records are available for a number of sites in Idaho, Oregon and Washington. Those sites with available records are shown at the end of this appendix.

Copies of individual weather records are available in printed and disk format. To obtain printed records, send a letter and a self-addressed business size envelope with postage affixed (two ounces of postage for the first record requested, one ounce for each additional) to:

Extension Crop Science
Crop Science Building, Room 131
Oregon State University
Corvallis, OR 97331-3002

If you would like one or several records in IBM-DOS format, send a formatted diskette (5¼ or 3½) and a self-addressed diskette mailer with postage attached to the address above.

If you are working across a number of locations and would like the entire set of weather records, send three diskettes with mailers and postage to the address above. Included on these diskettes will be a program called MATCHIT. MATCHIT is a program to match a field site to a site with a historic weather record. MATCHIT runs as an executable program. It first asks for acceptable variance ranges for latitude, longitude and elevation and then for the latitude, longitude and elevation of your site. It searches available records for those locations which fall within the range specified i.e. if a range of 2 is specified for latitude and the latitude of the site is 45 degrees, it will select as a match latitudes between 43 and 47, then check for matches of longitude and elevation.

The results are printed on the screen and are also in a file called MATCH.DAT. To print the file on a printer, at the DOS prompt type: type MATCH.DAT>prn.

MATCH.DAT is overwritten when the program is rerun. To keep a file from being overwritten COPY it to another filename. The file MATCH.DAT is required by MATCHIT so DO NOT rename it or the program will not run.

The data in the 30 yr. average files are as follows:

col 1:	day of the year
col 2:	month
col 3:	day of the month
col 4:	maximum temperature (F)
col 5:	minimum temperature (F)
col 6:	precipitation (in.)

CITY	COUNTY	STATE	LATITUDE DEG.	MIN.	LONGITUDE DEG.	MIN.	ELEVATION FT.
ANTELOPE	WASCO	OR	44	55	120	44W	2840
ARLINGTON	GILLIAM	OR	45	43	120	12W	285
AUSTIN	GRANT	OR	44	35	118	30W	4213
BAKER	BAKER	OR	44	50	117	49W	3368
BEND	DESCHUTES	OR	44	4	121	19W	3650
BEULAH	MALHEUR	OR	43	55	118	10W	3270
BROTHERS	DESCHUTES	OR	43	48	120	36W	4640
BURNS	HARNEY	OR	43	35	118	57W	4140
CHEMULT	KLAMATH	OR	43	14	121	47W	4760
CHILOQUIN	KLAMATH	OR	42	39	121	57W	4155
CONDON	GILLIAM	OR	45	14	120	11W	2830
CRATERLAKE	KLAMATH	OR	42	54	122	8W	6475
DALLES	WASCO	OR	45	36	121	11W	280
DANNER	MALHEUR	OR	42	56	117	20W	4225
DAYVILLE	GRANT	OR	44	33	119	39W	2260
DUFUR	WASCO	OR	45	27	121	8W	1330
ELGIN	UNION	OR	45	34	117	55W	2655
ENTERPRISE	WALLOWA	OR	45	24	117	16W	3880
FOSSIL	WHEELER	OR	45	0	120	13W	2650
FREMONT	LAKE	OR	43	20	121	10W	4512
GRIZZLY	JEFFERSON	OR	44	31	120	56W	3635
HALFWAY	BAKER	OR	44	53	117	7W	2670
HARTMTNREFUGE	LAKE	OR	42	33	119	39W	5616
HEPPNER	MORROW	OR	45	22	119	33W	1885
HERMISTON	UMATILLA	OR	45	49	119	17W	624
HOODRIVER	HOODRIVER	OR	45	41	121	31W	500
HUNTINGTON	BAKER	OR	44	21	117	16W	2130
IONE (PCP ONLY)	MORROW	OR	45	19	119	51W	2130
KENT	SHERMAN	OR	45	12	120	42W	2720
KLAMATHFALLS	KLAMATH	OR	42	12	121	47W	4098
LAKEVIEW	LAKE	OR	42	13	120	22W	4778
MALHEURREFUGE	HARNEY	OR	43	17	118	50W	4109
MALHEUREXPSTN	MALHEUR	OR	43	59	117	1W	2225
MCDERMITT	MALHEUR	OR	42	25	117	52W	4464
METOLIUS	JEFFERSON	OR	44	35	121	11W	2500
MIKKALO	GILLIAM	OR	45	28	120	21W	1550
MILTON FREEWATER	UMATILLA	OR	45	57	118	25W	970
MINAM	WALLOWA	OR	45	41	117	36W	3615
MORO	SHERMAN	OR	45	29	120	43W	1870
NYSSA	MALHEUR	OR	43	52	117	0W	2175
OCHOCO	CROOK	OR	44	24	120	26W	3975
ONTARIO	MALHEUR	OR	44	3	116	58W	2145
OWYHEEDAM	MALHEUR	OR	43	39	117	15W	2400
P-RANCHREFUGE	HARNEY	OR	42	49	118	53W	4195
PAISLEY	LAKE	OR	42	42	120	32W	4360
PENDAP	UMATILLA	OR	45	41	118	51W	1492
PENDEX	UMATILLA	OR	45	43	118	38W	1487
PILOT ROCK	UMATILLA	OR	45	29	118	49W	1720
PRINEVILLE	CROOK	OR	44	21	120	54W	2840
REDMOND	DESCHUTES	OR	44	16	121	10W	3020

CITY	COUNTY	STATE	LATITUDE DEG.	LATITUDE MIN.	LONGITUDE DEG.	LONGITUDE MIN.	ELEVATION FT.
RICHLAND	BAKER	OR	44	46	117	10W	2215
ROUNDGROVE	KLAMATH	OR	42	20	120	53W	4888
SENECA	GRANT	OR	44	8	118	58W	4660
SQUAWBUTTE	HARNEY	OR	43	29	119	43W	4660
UKIAH	UMATILLA	OR	45	8	118	56W	3355
UNION	UNION	OR	45	13	117	53W	2765
UNITY	BAKER	OR	44	26	118	14W	4031
VALE	MALHEUR	OR	43	59	117	15W	2240
WALLA WALLA 13ESE	UMATILLA	OR	46	0	118	3W	2400
WALLOWA	WALLOWA	OR	45	34	117	32W	2923
WASCO	SHERMAN	OR	45	35	120	42W	1264
WICKIUPDAM	DESCHUTES	OR	43	41	121	41W	4358
ANATONE	ASOTIN	WA	46	8	117	8W	3570
DAVENPORT	LINCOLN	WA	47	39	118	9W	2460
DAYTON 1WSW	COLUMBIA	WA	46	19	118	0W	1557
EPHRATA AP	GRANT	WA	47	19	119	31W	1259
HARTLINE	GRANT	WA	47	41	119	6W	1910
HATTON 9ESE	ADAMS	WA	46	45	118	39W	1430
LACROSSE	WHITMAN	WA	46	49	117	53W	1480
LIND 3NE	ADAMS	WA	47	0	118	35W	1630
ODESSA	LINCOLN	WA	47	20	118	41W	1540
POMEROY	GARFIELD	WA	46	28	117	37W	1810
PULLMAN 2NW	WHITMAN	WA	46	46	117	12W	2545
RICHLAND	BENTON	WA	46	19	119	16W	373
ROSALIA	WHITMAN	WA	47	14	117	22W	2400
SMYRNA	GRANT	WA	46	50	119	40W	560
SPOKANE	SPOKANE	WA	47	38	117	32W	2356
SPRAGUE	LINCOLN	WA	47	18	117	59W	1920
WALLA WALLA	WALLAWALLA	WA	46	2	118	20W	949
WILBUR	LINCOLN	WA	47	45	118	42W	2160
ABERDEEN EXPT	BINGHAM	ID	42	57	112	50W	4405
ARBON 2NW	POWER	ID	42	30	112	34W	5170
BOISE AP	ADA	ID	43	34	116	13W	2838
BONNERSFERRY 1SW	BOUNDARY	ID	48	41	116	19W	1860
BRUNEAU	OWYHEE	ID	42	53	115	48W	2530
BURLEY AP	CASSIA	ID	42	32	113	46W	4157
CASCADE 1NW	VALLEY	ID	44	32	116	3W	4896
COEUR D ALENE RS	KOOTENAI	ID	47	41	116	45W	2158
DIXIE	IDAHO	ID	45	33	115	28W	5620
GRACE	CARIBOU	ID	42	35	111	44W	5550
GRANGEVILLE	IDAHO	ID	45	55	116	8W	3360
HOLLISTER	TWIN FALLS	ID	42	21	114	34W	4525
ID. FALLS AP	BONNEVILLE	ID	43	21	112	4W	4730
ID. FALLS 46W	BUTTE	ID	43	32	112	57W	4938
LEADORE 2	LEMHI	ID	44	41	113	21W	6000
MALAD CITY	ONEIDA	ID	42	10	112	17W	4470
MOSCOW UNIV.	LATAH	ID	46	44	116	58W	2660
MTN HOME	ELMORE	ID	43	8	115	42W	3190
NEZ PERCE	LEWIS	ID	46	15	116	15W	3145
PALISADES	BONNEVILLE	ID	43	22	111	14W	5385

			LATITUDE		LONGITUDE		ELEVA-TION
CITY	COUNTY	STATE	DEG.	MIN.	DEG.	MIN.	FT.
REYNOLDS	OWYHEE	ID	43	12	116	45W	3930
RICHFIELD	LINCOLN	ID	43	4	114	9W	4306
ST ANTHONY 1WNW	FREMONT	ID	43	58	111	43W	4950
THREE CREEK	OWYHEE	ID	42	5	115	15W	5460
WEISER 2SE	WASHINGTON	ID	44	14	116	57W	2103

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