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AE 87002

April 1987

PREDICTING THE GROWTH STAGE OF
WHEAT IN THE NORTHERN PLAINS:
PROGRAM DOCUMENTATION

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ACKNOWLEDGEMENTS

The authors would like to thank the following people for their assistance during the development of this program:

Dr. Ed Vasey, Extension Soils Specialist, North Dakota State University, for reviewing the program and documentation, and for his support and suggestions throughout the development of the program.

Dr. Carl Fanning, Extension Soils Specialist, North Dakota State University, for reviewing the documentation and for valuable comments and suggestions concerning the use of the program.

Dr. Duane Berglund, Assistant Director, NDSU Cooperative Extension Service, for reviewing the program's documentation.

Terry Gregoire, Area Extension Agronomist, NDSU Cooperative Extension Service, for reviewing the program and documentation, and for giving valuable suggestions on program enhancements.

Andy Swenson, Microcomputer Specialist, NDSU Cooperative Extension Service, for reviewing the programs structure and making suggestions for improvement.

INTRODUCTION

Constant advancements in agricultural technology are challenging producers to become more precise in their management practices. The increased use of herbicides, fungicides, fertilizers, and growth regulators in intensive management of spring wheat requires producers to have a knowledge of spring wheat growth stages in order to apply chemicals in a timely manner so that maximum economic yields (MEY) can be reached.

In July 1986, producers, private industry personnel, and University researchers attended a workshop in Bismarck, North Dakota entitled "Implementing Maximum Economic Wheat Yields in the Northern Great Plains". This workshop was put together by the NDSU Cooperative Extension Service. As a result of this workshop, the authors recognized that computer software was needed to help in predicting the growth stage of spring wheat. Software of this nature would be a great asset in helping producers using intensive spring wheat management practices.

The Growth Stage prediction model is designed to help determine the growth stage of spring wheat. The program uses growing degree days to predict the growth stage of spring wheat using the Haun growth stage scale. This scale is simple and precise. A number is assigned to each leaf on the main stem of the plant. Most spring wheat varieties develop eight leaves on the main stem. When the eighth leaf is fully developed, the Haun growth stage designation is 8.0. Four additional growth units (i. e., flag leaf extension, boot stage, heading, and head extension) follow the growth stage of the last leaf. These growth stages are also numbered consecutively (9.0 through 12.0 for eight-leaved varieties). The number of each plant part being described can be subdivided into decimal fractions, or substages, to give more detail to the growth stage. This substage designation is determined by comparing the length of the developing leaf to the length of the last fully developed leaf. For example, if the second leaf is fully developed and the third developing leaf is one-half the length of the fully developed second leaf, the Haun growth stage is 2.5 (i. e., the two and one-half leaf stage). An excellent description of the Haun growth stage scale is given by Bauer (1, 2, 3).

The development rate of spring wheat is heat unit driven and closely related to air temperature. Although the growth stage of spring wheat can be determined visually by field inspection, the growing degree days (GDD) or heat unit approach offers a precise method for determining spring wheat growth stage. This system relates plant development rate to air temperature and requires a person to keep a daily record of maximum and minimum air temperatures for calculating the daily growing degree days and maintaining a summation of the daily growing degree days. The formula for calculating daily growing degree days is:

$$DGDD = \frac{\text{Max T} + \text{Min T} - \text{Base T}}{2}$$

2

where: DGDD = Daily Growing Degree Days
 Max T = Maximum temperature of the day
 Min T = Minimum temperature of the day
 Base T = A temperature below which no development occurs for a given plant species (32 degrees F for spring wheat.)

Since spring wheat development rate is affected by temperature, a certain minimum temperature is required before any plant development can occur. At temperatures above this minimum, plant development rate increases as temperature increases up to an optimum temperature. At temperatures above the optimum, plant development rate retards in direct proportion to the amount the actual temperature exceeds the optimum temperature.

To account for temperatures which prevent or retard plant growth, the DGDD formula for spring wheat is adjusted for extreme low and high temperatures. If the low temperature (Min T) is less than 32 degrees F, it is set equal to 32 degrees F. If the high temperature for the day is above 70 degrees during the period of seedling through the 2.0 growth stage, or 95 degrees F after the 2.0 growth stage, it is set equal to 70 degrees or 95 degrees F, respectively. This allows for a more precise estimate of the spring wheat growth stage.

PROGRAM DESCRIPTION

The Growth Stage program was designed for use on the IBM Personal Computer and compatibles. The program was developed for use on the Lotus 1-2-3 spreadsheet program to allow users to keep maximum and minimum daily temperature records for their area to calculate growing degree days and consequently determine the growth stage of spring wheat using the Haun scale. This provides a fast and precise method for determining growth stages for many fields, thus allowing for timely decisions for the proper application of chemicals.

STARTING THE PROGRAM

To run the Growth Stage program, insert the Lotus 1-2-3 system disk in drive "A" and the Growth Stage program disk in drive "B" and turn on the computer. Enter the date and time as requested. Following the entry of the date and time, the initial menu of Lotus 1-2-3 will appear on the screen. Press the enter key to enter the Lotus 1-2-3 worksheet. One more screen will appear before the Lotus worksheet appears. Press the enter key as instructed by the screen. The following screen will appear (screen A):

1-DESCRIBE 2-RUN 3-EXIT
Description of program

```
* * * * *
*           GROWTH STAGE           *
*           A Spreadsheet Program Predicting
*           the Growth Stage of
*           * SPRING WHEAT *
*           In the Northern Great Plains
* * * * *
```

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- PRESS:
1. For a description of the program.
 2. To run the Growth Stage Program.
 3. To exit the program.

For a brief description of the program, press the "1" key. The following screen will appear:

1-CONTINUE
Return to screen 1

THE GROWTH STAGE PREDICTION MODEL

This program was designed to help farmers in the Northern Great Plains determine the growth stage of spring wheat using growing degree days (GDD) and the Haun scale for spring wheat growth stage. The program allows the user to keep and update temperature records for April, May, June, July, August, and September for the purpose of monitoring growing degree days and predicting the growth stage of spring wheat. This will help producers manage fields for the timely application of herbicides, fungicides, growth regulators, and fertilizers.

PLEASE PRESS THE NUMBER "1" KEY TO RETURN TO THE MAIN MENU.

Again, press the "1" key (or enter) to return to the main menu. Select menu option "2" to run the program. When this

option is selected, the program is loaded into the computer and the following screen appears (screen 1):

```

                                CMD MENU
RUN UPDATE PRINT HAUNexplain INPUTS SAVE QUIT
Run the growth stage predictor

*****
                                GROWTH STAGE PREDICTOR
                                FOR SPRING WHEAT

TODAYS DATE:      MONTH      DAY      YEAR
                   5         15       87

FIELD              FIELD      DAYS      ACCUM      HAUN
                   PLANTING DATE SINCE      GDD        STAGE
                   MONTH      DAY  PLANTING
-----
Field #1           4         1       45       700       5.3
Field #2           4         5       41       655       4.9
Field #3           4         7       39       626       4.7
Field #4           4        10       36       579       4.4
Field #4           4        12       34       549       4.2
Field #6           4        15       31       506       3.9
*****

```

MENU OPTIONS

Note the menu options at the top of screen 1. By moving the cursor to the right, each option is reverse-highlighted, and a description of what the option does appears under the option as it becomes highlighted. These menu options are described as follows in the order they appear on the screen:

- RUN - Run the growth stage program.
- UPDATE - Update temperature records.
- PRINT - Print temperature records, growth stage determination.
- HAUNexplain - Series of screens explaining the HAUN STAGE scale.
- INPUTS - Assist user in program operation (inputs, etc.)
- SAVE - Save the current worksheet.
- QUIT - Exit the growth stage program (automatically saves your work).

To exit this menu at any time, press Ctrl-Break. To re-enter the main menu, simply press Alt-M. Each of these menu options will be explained in the following sections.

INPUTS

When using the program for the first time, select the INPUTS option from the main menu first. The INPUTS option is a series of three screens which will aid in inputting information and interpreting the results.

To select the INPUTS option, simply move the cursor to the right to highlight the INPUTS option and then press enter, or type the letter "I". The following series of screens (3 in all) will appear.

CMD MENU

1-CONTINUE

Continue to next explanation screen

* USER HELP SCREEN 1 *

INFORMATION INPUTS

1. TODAY'S DATE (MONTH, DAY, YEAR): For example, if you planted a field on April 1 and it is now May 15 and you wish to determine the growth stage for the field, enter 5 15 87 under the appropriate heading (MONTH, DAY, YEAR).
2. FIELD: Enter a description of the field for which you want to determine the growth stage. Some examples include the North 40, Lena's rented acres, Mom's quarter, etc.
3. FIELD PLANTING DATE (MONTH, DAY): Enter the date the field was planted (i. e. April 15 is entered as 4 and 15 under each respective column heading).

1-CONTINUE

Continue to next explanation screen.

* USER HELP SCREEN 2 *
EXPLANATION OF COLUMN TITLES

This screen explains the growth stage predictor table.

1. DAYS SINCE PLANTING: The number of days which have elapsed between the planting date of the field and the date entered for TODAYS DATE. For example, if the field was planted on April 1 and you entered April 20 as todays date, 20 days have gone by since the field was planted.
2. ACCUM GDD: Accumulated Growing Degree Days for this field between the date entered in TODAYS DATE and the FIELD PLANTING DATE.
3. HAUN STAGE: This is the growth stage of the crop in the described field for the time period elapsed between the FIELD PLANTING DATE and the date entered in TODAYS DATE.

1-RETURN

Return to main menu and screen 1.

* USER HELP SCREEN 3 *
TEMPERATURE RECORD UPDATING

1. MAX TEMP: In this column, enter the maximum daily temperature which has occurred in your area.
2. MIN TEMP: In this column, enter the minimum daily temperature which has occurred in your area.
3. DAILY GDD: In this column, the computer calculates the growing degree days for the MAX TEMP and MIN TEMP values which you have entered for that day.
4. ACC. GDD: In this column, the computer keeps a running total of ACCUMULATED GROWING DEGREE DAYS for the month.

UPDATE

When the UPDATE option is selected from the command menu, the following menu appears:

Please select one:

GROWTH STAGE

PREDICTOR

* UPDATE MENU *

- 1 Update April Temperatures
- 2 Update May Temperatures
- 3 Update June Temperatures
- 4 Update July Temperatures
- 5 Update August Temperatures
- 6 Update September Temperatures
- 7 Return to main menu

CHOICE: 2

Note that there are 6 months for which temperature records need to be kept. Even though you may not plant until mid to late April, or even in May in some cases, it is important to keep up the temperature records from the date the first field was planted. Also, the program MUST have maximum and minimum temperature values entered for EACH day of the month. Otherwise, the program WILL NOT work.

Table 1 is a sample temperature record for the month of April. The only two inputs required by the user are the minimum and maximum daily temperatures. The program will automatically calculate the daily growing degree days and accumulated growing degree days for you. When you have finished updating a temperature record, simply press the enter key. The program will calculate the worksheet and return to the main menu.

Table 1. April Temperature Record *

Month	Day	MAX TEMP	MIN TEMP	DAILY GDD	ACC. GDD
April	1	50	32	9	9
April	2	55	29	12	21
April	3	54	31	11	32
April	4	57	27	13	45
April	5	60	29	14	59
April	6	62	30	15	74
April	7	60	40	18	92
April	8	49	43	14	106
April	9	51	42	15	121
April	10	50	45	16	137
April	11	48	44	14	151
April	12	45	43	12	163
April	13	52	42	15	178
April	14	59	36	16	194
April	15	60	32	14	208
April	16	62	30	15	223
April	17	59	29	14	237
April	18	64	27	16	253
April	19	66	33	18	271
April	20	68	39	22	293
April	21	67	37	20	313
April	22	67	29	18	331
April	23	71	33	20	351
April	24	61	40	19	370
April	25	61	33	15	385
April	26	52	45	17	402
April	27	54	28	11	413
April	28	42	27	5	418
April	29	48	30	8	426
April	30	47	31	8	434
APRIL TOTAL:				-----	434

Source: 1984 Weather Almanac of Climatic Data for Fargo, ND.
 Compiled by Dr. J. W. Enz, State Climatologist, NDSU,
 Fargo, ND.

NOTE: DAILY GDD = Daily Growing Degree Days
 ACC. GDD = Accumulated Growing Degree Days

RUN

Selecting the RUN option from the main menu causes the program to determine the growth stage of spring wheat. The program prompts the user for the number of spring wheat fields (up to six fields), then permits entry of 1) the current date; 2) the name or some other description of each field; and 3) the

planting date (month and day) of each field. Entry of inputs is accomplished by moving the cursor to the desired column and entering the required information.

After you are finished entering the required inputs, simply press the enter key without typing anything. The computer will then ask you the following question:

Is everything correct (1=y, 0=n)?

Please check over all your entries to be certain they are correct. If you find any mistakes in your entries, press the "0" (zero) key and the enter key. The program will then allow you to correct any errors, and will ask you the above question again before proceeding. If everything is correct, press the "1" key and the enter key. The following screen will appear:

```
*****  
*                                     *  
*           PLEASE WAIT              *  
*                                     *  
*           GROWTH STAGE             *  
*                                     *  
*           BEING DETERMINED        *  
*                                     *  
*****
```

The program calculates the growth stage of each field by summing the total growing degree days between the planting date and the date in question. The accumulated growing degree days are then entered into a regression equation to determine the growth stage according to the Haun scale. The equation for determining the Haun growth stage is listed as follows:

$$h = 0.19503912 + (0.0072501424 * AGDD)$$

where: h = Haun growth stage
AGDD = accumulated growing degree days

This equation predicts the growth stage of spring wheat with approximately 98% accuracy.

After the growing degree days have been totalled between the dates in question, the worksheet is calculated to determine the growth stage for each field, the program returns to screen 1, and the main menu appears at the top of the screen.

An example will help to illustrate how the program operates. Suppose a producer planted wheat on 6 fields during April. He has kept updating his temperature records since April 1 by using the UPDATE menu option. It is now May 15 and the producer wants to know what the growth stage of each field is.

After entering the required inputs, the computer calculates the growth stage of the crop, and the following screen appears (similar to screen 1):

```

                                CMD MENU
RUN  UPDATE  PRINT  HAUNexplain  INPUTS  SAVE  QUIT
Run the growth stage predictor

*****
                                GROWTH STAGE PREDICTOR
                                FOR SPRING WHEAT

                                MONTH      DAY      YEAR
TODAYS DATE:                   5        15        87

                                FIELD      DAYS      ACCUM      HAUN
                                PLANTING DATE SINCE      GDD      STAGE
                                MONTH      DAY  PLANTING
-----
Field #1                       4         1        45        700        5.3
Field #2                       4         5        41        655        4.9
Field #3                       4         7        39        626        4.7
Field #4                       4        10        36        579        4.4
Field #4                       4        12        34        549        4.2
Field #6                       4        15        31        506        3.9
*****

```

Note that the program calculates the number of days that have elapsed since planting (DAYS SINCE PLANTING column), the growing degree days that have accumulated for each field (ACCUM GDD column), and the Haun growth stage. For the fields in this example, the producer may consider broadleaf herbicide applications of Glean, Buctril, or MCPA.

Obviously, this program is useful in that a producer can determine the growth stage for many fields planted on different days in a matter of minutes.

HAUNexplain

The HAUNexplain menu option is a series of 6 screens which is designed to help the user understand the Haun growth stage scale designations. To select this menu option, simply move the cursor to the right to highlight this option and press the enter key, or type the letter "H". The following series of screens will appear (6 in all):

CMD MENU

1-CONTINUE 2-RETURN
Continue to next screen

HAUN GROWTH STAGE INTERPRETATION SCREENS

* PLEASE NOTE THE FOLLOWING *

The following screens are designed to help you interpret the numerical Haun growth stage scale. These numeric scale designations describe the growth stage for the * MAIN STEM * of the plant, not the tillers. Please keep this in mind as you view these screens.

PLEASE PRESS "1" OR "ENTER" TO CONTINUE

CMD MENU

1-NEXT SCREEN 2-RETURN 3-PRINT
Move to Haun scale interpretation screen #2

HAUN STAGE INTERPRETATION SCREEN #1

WHEN THE
HAUN STAGE NUMBER IS:

THE VISUAL STAGE OF GROWTH IS:

0.5

One-half leaf stage (emergence)

1.0

One fully developed leaf
(1 leaf stage)

1.5

One and one half fully developed
leaves (1 1/2 leaf stage)

2.0

Two fully developed leaves
(2 leaf stage)

2.5

Two and one-half fully developed
leaves (2 1/2 leaf stage)

3.0

Three fully developed leaves
(3 leaf stage)

1-NEXT SCREEN 2-RETURN 3-PRINT
 Move to Haun scale interpretation screen #3

HAUN STAGE INTERPRETATION SCREEN #2

WHEN THE
 HAUN STAGE NUMBER IS:

THE VISUAL STAGE OF GROWTH IS:

3.5

Three and one-half fully developed leaves (3 1/2 leaf stage)
 Tillers starting to develop

4.0

Four fully developed leaves (4 leaf stage)

4.5

Four and one-half fully developed leaves (4 1/2 leaf stage)

5.0

Five fully developed leaves (5 leaf stage)

5.5

Five and one-half fully developed leaves (5 1/2 leaf stage)

1-NEXT SCREEN 2-RETURN 3-PRINT
 Move to Haun scale interpretation screen #4

HAUN STAGE INTERPRETATION SCREEN #3

WHEN THE
 HAUN STAGE NUMBER IS:

THE VISUAL STAGE OF GROWTH IS:

6.0

Six fully developed leaves (6 leaf stage) jointing started

6.5

Six and one-half fully developed leaves (6 1/2 leaf stage)

7.0

Seven fully developed leaves (7 leaf stage)

7.5

Seven and one-half fully developed leaves (7 1/2 leaf stage)

8.0

Eight fully developed leaves (8 leaf stage) Flag leaf present and starting to extend.

1-NEXT SCREEN 2-RETURN 3-PRINT
 Move to Haun scale interpretation screen #5

HAUN STAGE INTERPRETATION SCREEN #4

WHEN THE HAUN STAGE NUMBER IS:	THE VISUAL STAGE OF GROWTH IS:
-----	-----
8.5	Flag leaf is fully developed and extending
9.0	Flag leaf fully extended, boot has started to swell
9.5	Wheat plant is now in boot stage heads becoming prominent in tillers
10.0	Head starting to emerge through collar.
10.2	Heading has started. Awns of head emerging from collar of flag leaf. Boot stage is now complete.

1-RETURN 2-PRINT
 Return to main menu and screen #1

HAUN STAGE INTERPRETATION SCREEN #5

WHEN THE HAUN STAGE NUMBER IS:	THE VISUAL STAGE OF GROWTH IS:
-----	-----
10.5	Heading about 50% complete.
11.0	Head has cleared the collar. Heading complete.
11.3	Heading completed, head extension taking place, flowering is occurring.
12.0	Flowering and head extension are now complete. Wheat plant is physiologically mature, ripening starting (Final stage of growth).

This series of screens is self explanatory and will help you to become familiar with the Haun growth stage scale. When using

this menu option, you may want to first obtain a printout of the screen containing the fields you entered. You can then compare the predicted growth stage values with the values and explanations on the help screens.

Also note that there are two additional menu options on each screen, "2-RETURN" and "3-PRINT". By moving the cursor to the right each of these menu options is explained. If you type "2", you will return to the main menu and screen 1. If you type "3", you will receive a printout of the screen that you are viewing. You may want to obtain a printout of each of these help screens to have as a reference when you go out into the field.

PRINT

Upon selection of the print menu option from the main menu, the following menu appears:

Please select one:

GROWTH STAGE

PREDICTOR

* PRINT MENU *

- 1 Print April Temperature Record
- 2 Print May Temperature Record
- 3 Print June Temperature Record
- 4 Print July Temperature Record
- 5 Print August Temperature Record
- 6 Print September Temperature Record
- 7 Print Growth Stage Determination
- 8 Return to Main Menu

CHOICE:

This menu allows the user to obtain a printout of the temperature records for each month as well as a printout of the screen containing the growth stage determination. To obtain a printout, please select the desired menu option and press enter. The program will print the desired menu option and return to the main menu.

SAVE

Selecting this menu option simply saves the current worksheet. Be sure to save the worksheet after you have updated temperature records. If you do forget, the QUIT option will

automatically save your work before exiting the program.

QUIT

Selecting this menu option causes the program to first save the worksheet (just in case you forget). The program then returns to screen A. From this screen, select option 3 to exit Lotus 1-2-3 and return to DOS.

ERROR SCREEN

Should the user incorrectly enter any of the inputs, the program will go to an error screen, which appears as follows:

CMD MENU

1-RETURN

Please press the "1" key to return to main menu.

* ERROR SCREEN *

By reaching this screen, you have made an error inputting your information. The most probable errors are listed below:

1. Planting month greater than current month (i. e., June before April).
2. Planting month OR current month less than 4 (i. e., April is the smallest).
3. Planting month greater than 6 (June). Wheat is not seeded past June 30 in the Northern Great Plains.
4. Current month greater than 9 (i. e., September is largest).
5. Too many days in the month (i. e., entering 32 in a month that has 31 days).

This screen lists the most common errors which can occur. If this screen is reached, please check the inputs to see that the error is corrected. Press the number "1" key and the enter key to return to the main menu.

One other possible error should be noted. If the main screen shows the letters ERR in the DAYS SINCE PLANTING column, then an error has been made entering the day of the month. The most common error is entering a 31 or 32 when the month has only 30 or 31 days. Please be sure to check dates carefully for accurate input.

SUMMARY

The Growth Stage program was developed to help producers save time in determining the growth stage of different fields of spring wheat. This allows the producer to carefully monitor each field for the timely application of chemicals.

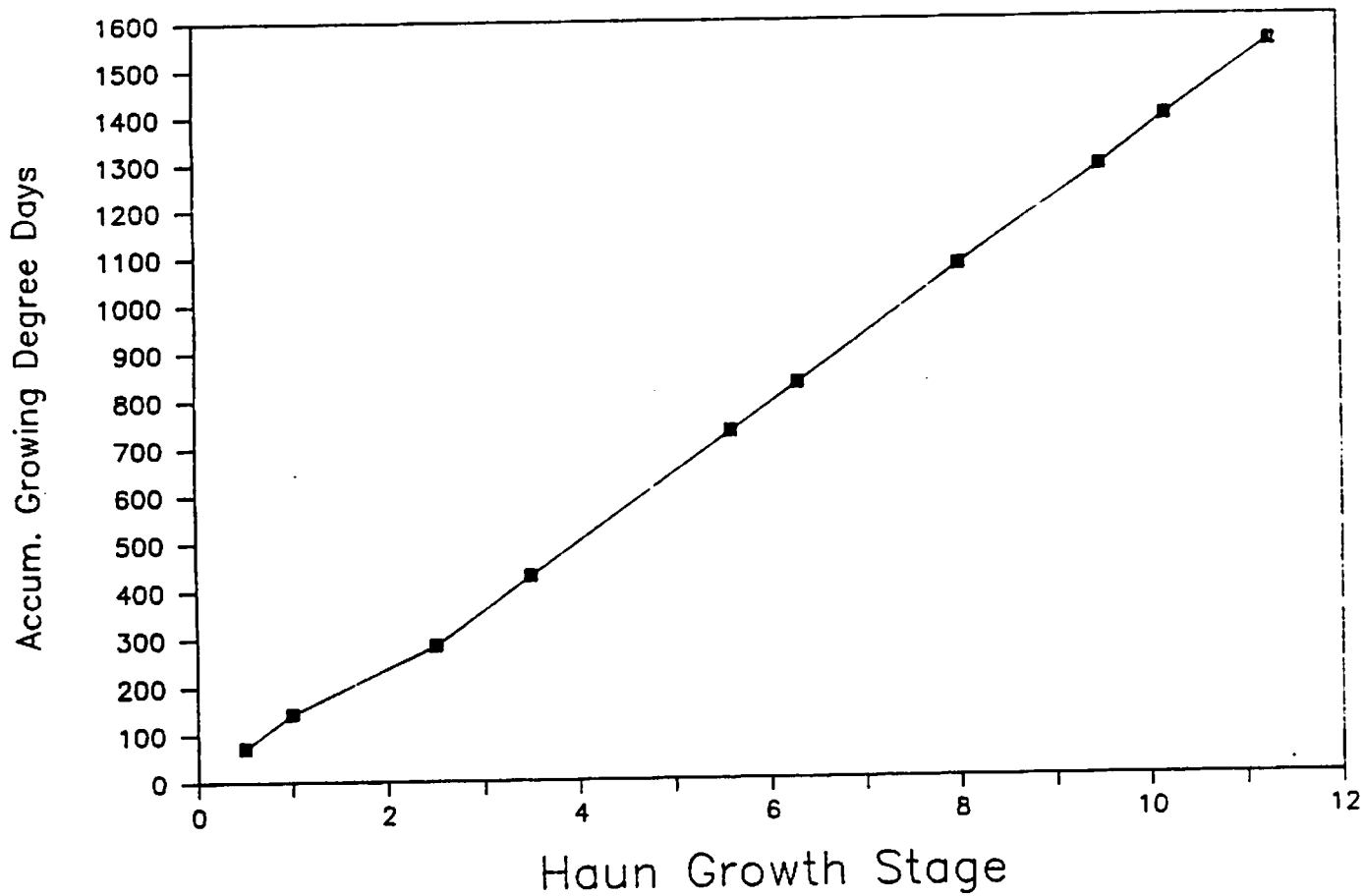
The appendix of this manual contains a graph showing the relationship between growing degree days and the Haun growth stage. Also included is a suggested form for keeping a temperature record on your farm and a table showing the numeric (Haun) growth stage related to the visual stage of spring wheat growth.

Extension bulletin EB-37, Use of Growing Degree Days to Determine Spring Wheat Growth Stages (Bauer et al. 1984), gives an excellent description of the Haun growth stage in relation to growing degree days.

APPENDIX

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AGDD vs. HAUN GROWTH STAGE



Accum. Growing Degree Days vs. Haun Growth Stage. Note the straight-line relationship.

TEMPERATURE RECORD
FOR
MONTH OF

DAY	MAX. TEMP.	MIN. TEMP.	DAY	MAX. TEMP.	MIN. TEMP.
1			16		
2			17		
3			18		
4			19		
5			20		
6			21		
7			22		
8			23		
9			24		
10			25		
11			26		
12			27		
13			28		
14			29		
15			30		
			31		

VISUAL STAGE OF WHEAT DEVELOPMENT ACCORDING TO HAUN SCALE
 (For the MAIN STEM of the plant, not the tillers)

<u>HAUN SCALE</u>	<u>VISUAL STAGE OF GROWTH</u>
0.5	Emergence
1.0	One fully developed leaf
2.0	Two fully developed leaves
3.0	Three fully developed leaves
3.5	Three and one-half fully developed leaves, tillers starting to develop
4.0	Four fully developed leaves
5.0	Five fully developed leaves
6.0	Six fully developed leaves, tillers very prominent Jointing now starting
7.0	Seven fully developed leaves
8.0	Eight fully developed leaves, flag leaf present and starting to extend
9.5	Flag leaf extension completed, wheat is in boot stage, heads prominent in tillers
10.2	Awns of head emerging from collar of flag leaf, boot stage complete, heading beginning
11.3	Heading completed, head extension taking place, flowering now occurring
12.0	Flowering and head extension complete; wheat is physiologically mature, ripening taking place

ADDITIONAL READING

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