BEANGRO V1.01

DRY BEAN CROP GROWTH SIMULATION MODEL

USER'S GUIDE

G. Hoogenboom, J. W. White, J. W. Jones,

and K. J. Boote

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Agricultural Engineering Department and Agronomy Department,

University of Florida, Gainesville, Florida 32611;

Department of Biological and Agricultural Engineering,

The University of Georgia, Georgia Station, Griffin, Georgia 30223;

IBSNAT Project, Department of Agronomy and Soil Science,

University of Hawaii, Honolulu, Hawaii 96822;

&

Bean Program, CIAT, Apartado Aereo 6713,

Cali, Colombia

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Department of Agricultural Engineering
10 Frazier Rogers Hall
University of Florida
Gainesville
Florida 32611, U.S.A.

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Chapter 1
INTRODUCTION

BEANGRO Version 1.01 is a process-oriented computer model which simulates vegetative growth, reproductive development and yield of common bean (*Phaseolus vulgaris* L.). The model has been developed under the auspices of the IBSNAT[1] (International Benchmark Sites Network for Agrotechnology Transfer) Project. BEANGRO was developed at the University of Florida by an interdisciplinary research team of crop physiologists and agricultural engineers of the Departments of Agronomy and Agricultural Engineering. During the initial phase of this project a close collaboration was established with the Bean Program of the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia.

The purpose of this guide is to provide users with information on how to implement and operate the model on their own microcomputers. Please contact the authors for any questions related to the operation of the model, modification and adaptation for your application, or any other problems or questions you might have.

General

The present version was developed by making numerous changes to earlier versions of the grain legume models SOYGRO and PNUTGRO (Hoogenboom et al., 1986). The original version of the soybean model SOYGRO was developed from 1980 to 1983 and published by Wilkerson et al. (1983a). That version was coupled to a soil water balance model developed by Jones and Smajstrla (1980) and documented as SOYGRO V4.2 (Wilkerson et al. 1983b). This model was tested for two cultivars (Bragg and Cobb) grown in Florida on sandy soils and under various irrigation regimes. It was subsequently used to study the economic risks of irrigation management in Florida (Swaney et al. 1983; Boggess et al. 1983; and Boggess and Amerling 1983). The soybean model SOYGRO also served as the crop component in an integrated pest management model called SICM (Soybean Integrated Crop Management model, Wilkerson et al., 1983b, Mishoe et al., 1984, Jones et al., 1986).

In 1983, a cooperative effort between the UF team and the IBSNAT Project was initiated. A major goal of this work was to make models more robust for use in other regions of the world where soils and climate differed from those in Florida. The first step in this process was to adapt a more general soil water model developed by Ritchie (1985), which included an evapotranspiration model developed by Priestley and Taylor (1972). In addition, a preliminary phenology model developed by J. W. Mishoe (unpublished) which predicts development of vegetative and reproductive stages of soybean in areas with diverse

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[1] IBSNAT is a program of the Agency of International Development, implemented by the University of Hawaii under the Cooperative Agreement No. AID/DAN-4054-A-00-7081-00.

photoperiods and temperatures was included in the model. A new version, SOYGRO V5.0, was documented and released (Wilkerson et al., 1985).

DSSAT

Over time, problems were discovered in applying SOYGRO V5.0 to diverse environments and we recognized the need to make a number of important changes in the model to improve its performance over a range of soils and environments. Concurrently the IBSNAT project had defined standard input and output formats for climate and soil in an attempt to make all the models in this project more useful with minimal incompatibilities. Thus, the soybean model was revised to fit this standard format. This standardization allowed the various crop models to be integrated into an overall Decision Support System for Agrotechnology Transfer (DSSAT) (IBSNAT, 1989; Jones, 1986; Jones et al., 1990b). Several other important changes were made in the model to improve its performance over a range of soils and environments.

The first version of the legume models which were adapted to fit within the general IBSNAT structure were SOYGRO Version 5.4 and PNUTGRO Version 1.00 (Boote et al., 1987; Jones et al., 1988). The Version 5.4 of SOYGRO (Jones et al., 1988) included the many improvements and enhancements. The coefficients for the phenology model were re-solved using the night temperature effects of Parker and Borthwick (1939) (Jones et al., 1991). More genetic coefficients were developed for a range of cultivars. Cohorts of flowers, pods, and seeds were now maintained through reproductive growth. Also improvements were made in several other submodels including those for soil water and photosynthesis. SOYGRO Version 5.41 and PNUTGRO Version 1.01 were created to correct some errors in the soil water balance that were found in earlier versions (Boote et al., 1988; Jones et al., 1988). At the same time other corrections were made in the two sets of source code. SOYGRO Version 5.42 and PNUTGRO Version 1.02 were developed to fit within the Decision Support System for Agrotechnology Transfer of the IBSNAT Project (Boote et al., 1989a; Jones et al., 1989). A new graphics feature was added to allow the user to graph simulated and measured soil water content data in the same graph, similar to the crop data graphics option. In addition as part of the DSSAT, long term simulations could be made for management and strategy analysis (IBSNAT, 1989).

BEANGRO V1.01

BEANGRO has been under development since 1986, parallel to the development and enhancement of the other two legume simulation models as described earlier. Although results have been reported at meetings and conferences, the first version of the model had not been made available for release to the general public (Hoogenboom et al., 1986; 1988b; 1989, 1990d). BEANGRO Version 1.01 is a modification of BEANGRO Version 1.00

(Hoogenboom et al., 1990f) and includes improvements with respect to temperature responses of the model and some other minor corrections.

The dry bean model includes many recent improvements which have not yet been incorporated in the released versions of SOYGRO (Version 5.42) and PNUTGRO (Version 1.02). Photosynthesis is now predicted on an hourly basis. Geometrical light interception is calculated for the both sunlit and shaded leaves in the canopy and for the bare soil between the rows. Based on this light interception and single leaf photosynthesis traits, total canopy photosynthesis is calculated and integrated over sunlit and shaded leaf area (Boote et al., 1990). As a result the geometry of the canopy is estimated, including the height and width of the row and the leaf angle distribution. BEANGRO also has an option in the sensitivity analysis section to modify the weather inputs to simulate the effects of global climate change on potential bean production. Maximum and minimum temperature, solar radiation, precipitation, and daylength can be modified. BEANGRO also responds to changes in ambient CO_2 concentration, affecting both photosynthesis and transpiration.

The model includes an option for sensitivity analysis which permits the user to interactively modify the variables which define the genetic coefficients. This option can be used to calibrate the model for new cultivars or to simulate growth and development of hypothetical lines for breeding applications. The user can also select an alternate crop parameter file to test alternate plant response to temperature or other environmental variables. Finally the user can modify a parameter which simulates the effect of poor soil fertility or other environmental conditions which in general reduce biomass production.

The output section of the model creates several files not yet available in the other grain legume models. One output file contains values related to the canopy photosynthesis, light interception and canopy geometry of the model. Some simple values related to nitrogen concentrations of leaves, stems, pods, and seeds are presented in the nitrogen output file. Both the nitrogen and photosynthesis values can be plotted with the graphics routines of the model which can be used to compare simulated and measured data. Finally two files contain summary information with respect to weather conditions during specific development periods during the growing season. These two files are written in a format which includes delimiters so that these files can be imported into LOTUS for further statistical analysis and graphics display.

Some details of earlier versions of BEANGRO have been described in several publications (Hoogenboom et al., 1988a, 1989, 1990c; Jones et al., 1990a). Further documentation is currently being developed; please contact the first author, i.e. Gerrit Hoogenboom[2], to request additional information about the current status of the documentation.

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[2] **Current address: Gerrit Hoogenboom, Department of Biological and Agricultural Engineering, The University of Georgia, Georgia Station, Griffin, GA 30223-1797, USA; Phone: 404-228-7216; FAX: 404-228-7270; Email: GHOOGEN @ GRIFFIN.UGA.EDU.**

Plans for future improvements of the models include: adding capabilities to simulate nitrogen uptake, fixation, and mobilization (Hoogenboom et al., 1990b); expansion and improvement of the evaporation and transpiration simulation similar to the hedge row and canopy photosynthesis modifications (Pickering et al., 1990); potential effects of diseases and insects; a modification of water flow, infiltration, and a perched water table; expansion of the root growth and water uptake; new generic input and output file structures; and simulation of phosphorus both in the soil and plant. A "generic" grain legume model, which can simulate grain legumes besides dry bean, peanut, and soybean is under development (Hoogenboom et al., 1990c).

The other two legume crop growth simulation models which are available and have been incorporated in DSSAT are for peanut (*Arachis hypogea* L.), PNUTGRO Version 1.02, (Boote et al., 1989a) and for soybean (*Glycine max* [L.] Mer.), SOYGRO Version 5.42, (Jones et al., 1989). Within the IBSNAT Project simulation models have been developed for corn (*Zea mays* L.), CERES-Maize Version 2.10 (Ritchie et al., 1989), and wheat (*Triticum aestivum* L.), CERES-Wheat Version 2.1 (Godwin et al., 1989). Crop models for sorghum, rice, millet, barley, and potato have been developed but have not been finalized and released yet. Please contact the IBSNAT[3] Project for further information about those models and their availability.

[3] IBSNAT Project, Department of Agronomy and Soil Science, College of Tropical Agriculture and Human Resources, University of Hawaii, 2500 Dole Street, Krauss Hall 22, Honolulu, Hawaii 96822.

Chapter 2
MODEL DESCRIPTION

BEANGRO V1.01 predicts dry matter growth, leaf area index (LAI), crop development, and final yield of common bean depending on daily weather data (precipitation, solar radiation, photoperiod, maximum and minimum air temperatures), soil profile characteristics, and crop management conditions. Soil parameters describe the ability of the soil profile to store water and to supply water to plant roots based on processes of runoff, percolation, and redistribution of water in a one-dimensional profile. Thus, soil characteristics and weather data are required inputs. The model also is sensitive to cultivar choice, planting date, row and plant spacings, and irrigation management options.

This version of BEANGRO was designed as a research tool. Users can input soil, weather, and management data as well as measured crop growth data from experiments or from farmers' fields for testing or validating the model for specific conditions. Experiments can be simulated with the model and compared in tabular and graphical forms with measured data. Scientists can easily conduct sensitivity analyses by interactively running the model with different combinations of soils, weather, cultivar and management factors. And finally, users can conduct risk analysis studies by simulating many cropping seasons over time and space by varying weather and soil inputs.

Pests are not included in the current model, although efforts with cooperators are underway to evaluate effects of insect damage on plants and pods. Also there are other factors, particularly various plant nutrients, that are not included in the present version of the model. Results from the model, therefore, should be viewed as potential yields under the specified regimes of weather, soil, and crop management condition. There could be other factors, such as pests, diseases, or poor fertility, which might be limiting to growth and development and further reduce yields.

Chapter 3
SYSTEM REQUIREMENTS

BEANGRO V1.01 was developed using IBM-AT (8 MHz), AST-386 (20MHz) and Everex Step-386 (33MHz) microcomputers; PC-DOS 3.3 and MS-DOS 3.31; Microsoft[4] Fortran Version 4.1 and Version 5.0, and Microsoft Quick Basic Version 4.0 and version 4.5. The model runs faster on machines with a 80386 or better CPU and a math coprocessor, a clock speed of 33 MHz or faster, and with all input and output files and executable code located on a hard-disk drive. BEANGRO will also run on a basic two-floppy disk drive microcomputer with a minimum memory requirement of 256K. However, this setup has some limitations and will result in long execution times.

Both the Fortran and Basic section of the BEANGRO model require DOS version 2.0 or higher. To display graphical results, your PC must have a graphics adapter (IBM Color Graphics Adapter [CGA] or Enhanced Graphics Adapter [EGA] or equivalent) and a color or monochrome graphics monitor with either a CGA or EGA screen resolution. The graphics section of the model will not operate with a Hercules graphics card.

On a two-floppy disk system, you are limited by the amount of storage space on your diskettes. You must allow room on your drive B: (Data Disk) for the output files created by the model and a work file for graphics display, which is approximately half the size of the OUT2.BN file. The size of the files depends upon the number of runs and the total number of simulated days in the output files. The number of days per run file can be reduced if you ask for less frequent output in option no. 2, "**Select Simulation Output Options**," after you have selected your experiment and treatment case study. Use a maximum of five runs per session if you have a two-floppy system and write the results to an output file every two days (default output frequency). If you exceed the amount of space available on the diskette, the graphics program will give you an error "*NOT ENOUGH SPACE FOR RANDOM WORK FILE.*"

A very basic microcomputer with 256K memory and two floppy drives has enough room on the floppy diskette for approximately 5 runs per session. If you run out of diskspace, the system will come to a halt during execution of the model or in the graphics portion while reading the output files generated by the model. If the system aborts because the computer ran out of diskspace you must reboot your system and rerun the model.

The BEANGRO model will run on all IBM PC's, XT's, AT's, PS/1's and PS/2's and true compatibles. Unfortunately we do not have unlimited access to hardware. We have successfully run BEANGRO on the on various microcomputers that meet the minimum requirements described above. In a benchmark comparison, the fastest run was made on a PC Brand 386 (33 MHz) with a math coprocessor and took 13 seconds. The slowest run

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[4] Microsoft Corporation, 10700 Northup Way, Bellevue, WA 98004.

was made on an IBM PC (4 Mhz) without a math coprocessor and took about 35 minutes. The run time of BEANGRO Version 1.01 was increased about 75 % over that of SOYGRO Version 5.42 primarily because of the hourly photosynthesis calculations.

Chapter 4
GETTING STARTED

BEANGRO V1.01 is supplied on four floppy diskettes: 1) Program, 2) Data, 3) Graphics, and 4) Source Code diskettes. A directory of each of these diskettes is contained in Tables 7, 8, 9, and 10, respectively (Appendix A). Before proceeding further, insert the diskettes, one by one, into drive A: and obtain a directory. If all the directories match the ones in Table 7-10, you may proceed. If there are differences, such as missing files, please contact the suppliers of the model before continuing.

A back-up copy of each diskette should be made before trying to run BEANGRO. All diskettes are supplied to you with write-protect tabs so that the model will not run with the disks you received. This will protect your original copies in case your execution copies are lost or damaged in some way. Please label your copied diskettes the same as the original ones. If you plan to run BEANGRO from the diskettes, then the Program (No. 1) and Graphics (No. 3) diskettes must contain the system file COMMAND.COM. If you run BEANGRO from your hard-disk, then you will not have to create these system diskettes. The step-by-step procedure for installing BEANGRO to run on diskettes and on hard-disk systems are given in Chapters 5 and 6, respectively.

When your microcomputer is booted (first turned on or when DOS is loaded) a file called CONFIG.SYS is used to establish the characteristics of the computer. To run BEANGRO, you must create the file CONFIG.SYS (or edit it if it is already on your disk). This is an essential file and BEANGRO will *NOT* run unless it is on your system disk (floppy or hard-disk). Please follow the instructions in Chapter 5 or Chapter 6, depending on your hardware, to create this file.

Chapter 5
RUNNING BEANGRO ON A TWO-DISKETTE SYSTEM

Installation

To run BEANGRO on a two-diskette system, you must format two of the four diskettes with the /S option, that is they must be formatted as system diskettes. Then, copy COMMAND.COM, ANSI.SYS, and GRAPHICS.COM from your DOS diskette to each of these two diskettes (No. 1 and 3). In addition, you must edit the CONFIG.SYS file and add the following three statements:

```
DEVICE = ANSI.SYS
FILES = 25
BREAK = ON
```

You need a total of 4 blank diskettes. The following list describes the step-by-step procedure for creating your diskettes to run BEANGRO.

1. Insert your DOS system diskette (Version 2.0 or higher) into drive A:

   Turn on the power to start the system.

2. Insert a blank diskette into drive B:

3. Enter:

   FORMAT B:/S
   N (In response to "*Format another (Y/N)*"
   COPY A:GRAPHICS.COM B:
   COPY A:ANSI.SYS B:

4. Remove the DOS system diskette from drive A:

5. Insert the distribution BEANGRO Program diskette (No. 1) into drive A:

6. Enter:

   COPY A:*.* B:

   The computer should terminate with "*3 files copied.*"

7. Use your editor to create the file CONFIG.SYS described above and save it to your B: diskette.

8. You now have your Program disk ready, and your computer will boot on this drive. Remove the diskettes from both drives.

9. Label the new diskette from drive B: "1. **PROGRAM BEANGRO V1.01.**"

10. Insert the DOS system diskette into drive A: again.

11. Insert a blank diskette into drive B:

12. Enter:

    FORMAT B:/S
    N (In response to *"Format another (Y/N)?"*
    COPY A:GRAPHICS.COM B:
    COPY A:ANSI.SYS B:

13. Remove the DOS diskette from drive A:

14. Insert the Graphics BEANGRO diskette (No. 3) into drive A:

15. Enter:

    COPY A:*.* B:

    The computer should terminate with *"19 files copied."*

16. Remove diskettes from both drives.

17. Label the diskette from drive B: "**3. GRAPHICS BEANGRO V1.01.**"

18. Insert DOS diskette into drive A:

19. Enter:

    DISKCOPY A: B:

20. Remove the system diskette from A:

21. Insert the BEANGRO Data diskette (No. 2) into A: and a blank diskette into drive B:. *Press any key to make the copy.*

22. Remove both diskettes and label the one from drive B: "**2. Data BEANGRO V1.01.**"

23. Enter Y in response to the prompt, *"Do you want to make another copy?"*

24. Insert the Source Code diskette (No. 4) into A: and a blank diskette into drive B:. *Press any key to make the copy.*

25. This will create a backup of the Source Code diskette. Note that this diskette is not required for running the model. It is required only if programming changes are to be made.

26. Remove the diskettes and label the one from drive B: as "**4. SOURCE CODE, BEANGRO V1.01.**"

Execution

To run BEANGRO on your two-diskette system use the following steps:

1. Insert Program diskette (No. 1) into drive A: and the Data diskette (No. 2) into drive B:

2. Turn on the power to the computer or reboot the system by depressing and holding the <CTRL> and <ALT> keys, then pressing the <DEL> key and releasing them all.

3. Enter:

   GRAPHICS

   to set up the computer to print out graphs of your results (if you wish to have graphs printed using the <Shift-PrtSc> or <Print-Screen> screen dump command).

4. Enter:

   BGRO

   to start the BEANGRO program.

5. After the simulation is finished you will be prompted to replace the Program disk (No. 1) with the Graphics disk (No. 3) to run the graphics section of the model.

   Press any key to continue.

You will be prompted to select items from screen menus to simulate growth and yield of a bean crop. An example run is included later in this User's Guide (Chapter 9).

Chapter 6
RUNNING BEANGRO ON A HARD-DISK SYSTEM

Installation

1. Start the system. If the system power is off, turn on the power. When the system is on, press and hold the <Ctrl> and <Alt> keys, then press the <Del> key, and then release them all to re-boot the system.

2. Create or edit the file CONFIG.SYS in the root directory, by entering:

   DEVICE = ANSI.SYS
   FILES = 25
   BREAK = ON

   Save the new or modified file CONFIG.SYS.

3. Create a subdirectory by entering:

   MD BEANGRO

4. Go into the new subdirectory by entering:

   CD BEANGRO

5. Copy BEANGRO Program, Data, and Graphics diskettes (No. 1, 2, and 3) into the subdirectory using the following steps:

   a. Insert BEANGRO program diskette (No. 1) into drive A:

   b. Enter:
   COPY A:*.* C:\BEANGRO

   The computer should terminate with "*3 files copied.*"
   BEANGRO can be installed on any partitioned harddrive and is not restricted to operation on Drive C: only.

   c. Remove BEANGRO Program diskette from drive A:

   d. Insert BEANGRO Data diskette (No.2) into drive A:

e. Enter:

COPY A:*.* C:\BEANGRO

or any other drive or directory where you want to run the model.

The computer should terminate with "*50 files copied.*"

f. Remove Data diskette from drive A:

g. Insert Graphics diskette (No. 3) into drive A:

h. Enter:

COPY A:*.* C:\BEANGRO

or any other drive or directory where you want to run the model.

The computer should terminate with "*19 files copied.*"

i. Remove the Graphics diskette

The following section is optional.

j. Insert Source Code diskette (No. 4) into drive A:

k. Enter:

COPY A:*.* C:\BEANGRO

or any other drive or directory where you want to run the model.

The computer should terminate with "*60 files copied.*"

l. Remove the Source Code diskette

Execution

After installing the model in subdirectory BEANGRO, you are ready to run the model by simply entering BEANGRO. Thereafter, whenever you start the computer to run the model, use the following steps:

1. Turn on the computer.
2. Enter:
   GRAPHICS
3. Enter:
   CD BEANGRO
4. Enter:
   BEANGRO

You will be prompted to select items from screen menus to simulate growth and yield of a bean crop. An example run is included later in this User's Guide in Chapter 9. Note that the command to start the model from the hard-disk is different from that used on the floppy-diskette system. Also note that you may wish to copy the source code from diskette No. 4 into the BEANGRO subdirectory on your hard-disk. However, you need to do this only if you want to make programming changes in the FORTRAN code. Example programs are included for compiling and linking the source code.

Chapter 7
SYSTEM SETUP FOR BEANGRO GRAPHICS

The BEANGRO graphics program is designed to allow users to plot simulated and observed data so they can visually evaluate the ability of the model to mimic experimental results. Users can select crop variables (such as leaf area index, seed weight, etc.), weather/soil variables, crop nitrogen variables, or photosynthesis data. When more than one BEANGRO simulation is performed in a session, the user can also select the run number for graphical analysis. For example, users could choose to plot seed weight for two different simulations, irrigated and rainfed. Or users could select to view leaf weight, seed weight, and total canopy weights for a single run. Up to six variables at one time per graphics display can be selected for viewing, from various run and variable combinations. There is a restriction, however. Because the graph has only one vertical axis, users should not select variables of different scales for viewing on the same graph (i.e., LAI and seed weight in kg/ha). After a graph is displayed on the screen, the user can press the <Shift> <PrtSc> or <Print-Screen> keys to print the graph on a printer (if a printer is available).

When BEANGRO graphics are run for the first time, the system will prompt you for the system setup with the following questions:

1) *Type drive and path of graphics program*

   If you are on a two-disk drive system enter: B:

   If you are on a hard-disk drive system enter: C:\BEANGRO or the appropriate drive and directory where you installed BEANGRO.

2) *Which data drive contains the selected data?*

   If you are on a two disk drive system enter: B:

   If you are on a hard-disk drive system enter: C: or the appropriate drive where you installed BEANGRO.

3) The following section describes how to set your monitor type and graphics-adapter card.

NOTE: The graphics section of BEANGRO V1.01 will not work on a system with a <u>HERCULES</u> graphics card[5].

Graphics Options Available

[1] - CGA-LOW - 320 x 200 pixels, 3 color graph

[2] - CGA-HIGH - 640 x 200 pixels, monochrome graph (HERCULES NOT AVAILABLE)

[3] - EGA-LOW - 640 x 200 pixels, 6 color graph, requires EGA

[4] - EGA-MED - 640 x 350 pixels, 3 color graph, requires EGA

[5] - EGA-HIGH - 640 x 350 pixels, 6 color graph, requires EGA & 128 video memory

Enter graphics option ?

Enter the Graphics Option appropriate to your setup and preferences. The greater the number of pixels, the higher the resolution on the screen (CGA is Color Graphics Adapter or regular color graphics; EGA is Enhanced Graphics Adapter or higher resolution graphics). If you enter the wrong option for your graphics setup, the program will abort. You can reset your graphics definitions by deleting file **"SETUP.FLE"** and in some cases also file **"SELPGM.DAT"** from either the graphics disk (No. 3) or your hard-disk (see next section).

4) *Would you like to save disk drive and graphics option for future runs ? Y/N*

If you answer **Y** to this prompt, you will not be asked the system setup questions again and a file, **"SETUP.FLE,"** will be created. If you answer **N**, the system will repeat the system setup question each time the graphics option is run. To change the system setup after you have answered **Y** to the setup question, delete the file **"SETUP.FLE."** In certain cases you also might have to delete the file **"SELPGM.DAT"** from either the graphics disk (No. 3) or your hard-disk.

[5] Currently there are utilities available which can emulate CGA graphics for a Hercules monochrome graphics card. One of these utilities, SIMCGA, can be obtained from the authors, although we do not guarantee that it will work for all Hercules or Hercules compatible cards.

Chapter 8
PROBLEMS

Many types of microcomputers currently are available on the market. We have been unable, therefore, to test the simulation model BEANGRO V1.01 on all possible systems. If the model does not work after you have created your floppies or hard-disk files, please check the instructions given in Chapters 5, 6, and 7. A check list of four possible problems follows.

1. The original disks will not run on your system because they do not include the required system files.

2. Either your "Program Disk" or "Graphics Disk" does not have a COMMAND.COM file.

3. Insufficient CPU memory (not diskspace) is available. Make sure that you have at least 256K of memory available, e.g. with the DOS command CHKDSK, and that you do not have any resident programs which use additional memory.

4. Files were inadvertently erased or copied with errors. Go through the copying process once more to check that you followed all the instructions correctly.

If problems persist and your system is "IBM compatible," please inform the authors about your problems. Make a copy of your error message and clearly describe what type of system you have: brand name, model type, amount of memory, video display, graphics card, printer, type and version of operating system and other information which can help determine the reason for your problems.

If the model executes, but aborts during the real-time running process, reboot the system and start again. If the same error occurs, try to choose a different experiment and treatment for the next run. If the model continues to abort, please make a screen dump of the error message, follow the instructions in No. 5 above and contact the authors of the model.

If the model operates correctly, but the graphics section does not work, check if you have a graphics board in your system. To be able to plot the results to the screen, a color graphics or monochrome (not HERCULES) graphics board is needed. Follow the instructions given in No. 5 above if the problem continues and contact the authors.

Specific Errors

In summary, possible errors which could occur are:

1. Wrong operating system.

2. Your machine is not a true "IBM compatible" microcomputer.

3. Not enough memory to execute the model section of BEANGRO.

4. No CONFIG.SYS file defined in your system.

5. Not enough disk space on either your floppy disk or your hard-disk to run the model.

6. Not enough memory to execute the graphics section of BEANGRO.

7. No graphics card present in your microcomputer.

8. You have a Hercules graphics card.

9. You used the wrong setup when you first defined your system in the graphics section of the model (see previous instructions).

10. You used the wrong batch file to run the model: BGRO is the command to run the model for a floppy disk system and BEANGRO is the command to run the model on a hard-disk system.

11. Your program disk is not placed in disk drive A: and your data disk is not placed in disk drive B:.

12. Some files are missing on your disks; in this case check your original copies or request another set of original copies from the authors.

Chapter 9
EXAMPLE RUN

An example run is provided below to demonstrate the model's operation and to provide users with data to compare with their results. There are various types of output from the model. The screen output is shown in the example below. Also, output data files are created on the floppy- or hard-disk to store screen output (OUT1.BN), simulated plant variables (OUT2.BN), weather and soil variables (OUT3.BN), plant nitrogen variables (OUT4.BN), photosynthesis and light interception variables (OUTP.BN), end of season summary results such as yield and season length, for each season simulated (OUT5.BN), and summary biomass, developmental and environmental variables (OUT8.BN and OUT9.BN). The last section in this report contains documentation on IBSNAT crop model input (Appendix B and C) and output files (Appendix D), including descriptions of files OUT1.BN, OUT2.BN, OUT3.BN, OUT4.BN, OUTP.BN, and OUT5.BN (Appendix F). Files OUT5.BN, OUT8.BN, OUT9.BN, and OUTP.BN were created after IBSNAT Technical Report 5 (IBSNAT, 1990a) was published, and therefore are not described in that report. In addition, some new variables were added to OUT2.BN and OUT3.BN to allow graphical display of more variables (Appendix E and F).

Before proceeding, users should follow the instructions given in this example run to confirm that their outputs are the same as those reported for the example. The example run was made by selecting from the "Case Study Experiments," the first experiment (1986 CIAT) and the first treatment in that experiment. Remember to enter GRAPHICS before running BEANGRO so that graphs which are displayed on the screen can be printed to your printer.

Simulation Model

To run the model on a floppy-diskette system, type **BGRO** (see Chapter 5 for detailed installation instructions and placement of disks in the disk drives). To run the model on a hard-disk system, type **BEANGRO** (see Chapter 6 for detailed installation instructions).

The following is an example of the output as it appears on the screen during the simulation and the different selections you can make as a user. The outputs of this example run are also shown in Appendix F and in the OUT?.BN files on the distribution diskette.

```
BEANGRO V1.01

Gerrit Hoogenboom, J.W. White, J.W. Jones, and K.J. Boote

Dept. of Biological and Agricultural Engineering, The University of
Georgia, Griffin, Georgia & University of Florida, Gainesville, Florida,
in cooperation with Bean Physiology Program, CIAT, Cali, Colombia.

    BEANGRO is a process oriented computer model, which simulates
vegetative growth, reproductive development, and yield of common bean
(Phaseolus vulgaris L.).  The BEANGRO model was adapted from the model
SOYGRO 5.42, which was originally developed at the University of Florida
to study irrigation and pest management decisions.  Some minor modifi-
cations in the code were made and parameters in the crop and cultivar
specific input files were changed, based on experimental and literature
data.  BEANGRO was development for use in the International Benchmark
Sites Network for Agrotechnology Transfer (IBSNAT) Project and has
input and output data structures, which are compatible with the Decision
Support System (DSSAT) of IBSNAT.  Users can simulate specific
experiments by either changing cultivar, soil, weather, or management
conditions, and compare simulated results with experimental data.
```

Press **Enter** or **Return**

```
                                          INST.  SITE  EXPT.
   CASE STUDY EXPERIMENTS                  ID     ID    NO    YEAR
   ---------------------------------      ----   ----  ----   ----
1)  3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES  CC     PA    29    1986
2)  ICTA-OSTUA,RABIA DE GATO,TURBO-III;1989 IG     QU    03    1989
3)  4 CULTIVARS, IRR. & NONIRRIGATED        UF     GA    01    1985
4)  2 CULTIVARS, 5 IRRIGATION TREATMENTS    UF     GA    01    1986

1]  <=== CASE STUDY SELECTED
    <--- NEW SELECTION?
```

Type: **1** and press **Enter** or **Return**

```
                                              INST.  SITE  EXPT.
NO.  3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES    ID     ID    NO    YEAR
---  ------------------------------------------------   ----  ----   ----
 1)  Porrillo Sin.  0.3 m row by 15 pl/m2      CC     PA    29    1986
 2)  Porrillo Sin.  0.3 m row by 30 pl/m2      CC     PA    29    1986
 3)  Porrillo Sin.  0.6 m row by 15 pl/m2      CC     PA    29    1986
 4)  Porrillo Sin.  0.6 m row by 30 pl/m2      CC     PA    29    1986
 5)  BAT 477        0.3 m row by 15 pl/m2      CC     PA    29    1986
 6)  BAT 477        0.3 m row by 30 pl/m2      CC     PA    29    1986
 7)  BAT 477        0.6 m row by 15 pl/m2      CC     PA    29    1986
 8)  BAT 477        0.6 m row by 30 pl/m2      CC     PA    29    1986
 9)  BAT 881        0.3 m row by 15 pl/m2      CC     PA    29    1986
10)  BAT 881        0.3 m row by 30 pl/m2      CC     PA    29    1986
11)  BAT 881        0.6 m row by 15 pl/m2      CC     PA    29    1986
12)  BAT 881        0.6 m row by 30 pl/m2      CC     PA    29    1986

1]  <=== TREATMENT SELECTED
    <--- NEW SELECTION?
```

Type: 1 and press Enter or Return

```
WHAT WOULD YOU LIKE TO DO ?

0)   RUN SIMULATION.
1)   SELECT SENSITIVITY ANALYSIS OPTIONS.
2)   SELECT SIMULATION OUTPUT OPTIONS.

<=== CHOICE? < DEFAULT = 0 >
```

Type: 0 and press Enter or Return

```
                  <=== RUN   1 IDENTIFIER ?
```

Type: Porrillo 1986 (Use a 5 character string for CGA display and a maximum of 14 characters for all other displays).

```
INPUT SUMMARY        RUN NO.  1          SIMULATION BEGINS : AUG 27

INST_ID: CC  SITE_ID: PA  EXPT_NO: 29  YEAR: 1986  TRT_NO:  1
EXPERIMENT    : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT     : Porrillo Sin.  0.3 m row by 15 pl/m2
WEATHER SET   : CIAT, PALMIRA, COLOMBIA       1986
VARIETY       : Porrillo Sintetico   PHOTOPERIOD GRP :  3 TEMPERATURE GRP :  1
IRRIGATION    : ACCORDING TO THE FIELD SCHEDULE
PLANTING DATE: SEP 26 PLANTS/M2: 15.00 ROW SPACING: .300m PLANT SPACING: .222m

SOIL PROFILE DATA  Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
SOIL ALBEDO  :  .09  U:11.0  SWCON:  .40  CURVE NO.: 84.0  PHFAC3:1.00
  DEPTH-m      LL      DUL     SAT    EXTR    INIT   ROOT    SWCN
  .00-  .05  .204     .340    .392   .136    .340  1.000    .000
  .05-  .15  .204     .340    .392   .136    .340  1.000    .000
  .15-  .25  .209     .345    .390   .136    .345   .750    .000
  .25-  .35  .209     .345    .390   .136    .345   .500    .000
  .35-  .50  .198     .335    .390   .137    .335   .350    .000
  .50-  .65  .185     .323    .395   .138    .323   .200    .000
  .65-  .80  .185     .323    .395   .138    .323   .150    .000
  .80-  .99  .201     .328    .408   .127    .328   .100    .000
  .99- 1.22  .198     .325    .410   .127    .325   .050    .000
 1.22- 1.37  .159     .288    .399   .129    .288   .000    .000
 1.37- 1.59  .110     .242    .402   .132    .242   .000    .000
 1.59- 1.84  .047     .177    .351   .130    .177   .000    .000
 1.84- 2.09  .050     .193    .410   .143    .193   .000    .000
            -----------------------------------
    SUM mm  313.6    593.2  824.2  279.5  593.2
                                              Press < ENTER > key to continue
```

Press Enter or Return

RUN NO. 1 SIMULATION OUTPUT

CC PA 1986 Porrillo 1986

DATE	CROP AGE	GROWTH STAGE	BIOMASS KG/HA	LAI	V-STAGE	WATER BALANCE COMPONENTS ES mm	EP mm	ET mm	RAIN mm	IRRIG mm	DROUGHT STRESS PHOTO	TURGOR
SEP 30	4	EMERGENCE	11.	.02	.0	69.	0.	69.	92.	30.	.000	.000
SEP 30	4	END JUVEN.	11.	.02	.0	69.	0.	69.	92.	30.	.000	.000
OCT 6	10	FLOWER IND	24.	.05	.9	95.	0.	95.	124.	30.	.000	.000
OCT 7	11	UNIFOLIOL.	28.	.07	1.0	99.	0.	99.	137.	30.	.000	.000
NOV 3	38	FLOWERING	1918.	4.07	8.3	155.	42.	196.	276.	30.	.000	.031
NOV 8	43	FIRST POD	2778.	5.32	9.7	157.	58.	216.	324.	30.	.000	.000
NOV 15	50	FULL POD	4187.	5.99	11.8	160.	85.	245.	327.	30.	.000	.000
NOV 16	51	FIRST SEED	4436.	6.08	12.1	161.	89.	250.	327.	30.	.000	.000
NOV 16	51	END MSNODE	4436.	6.08	12.1	161.	89.	250.	327.	30.	.000	.000
NOV 21	56	END POD	5442.	5.60	12.1	162.	107.	270.	329.	55.	.000	.000
NOV 26	61	END LEAF	6363.	4.88	12.1	165.	125.	290.	355.	55.	.000	.000
NOV 30	65	PHYS. MAT	6920.	4.30	12.1	166.	136.	302.	368.	55.	.000	.000
DEC 9	74	HARV. MAT	6037.	.28	12.1	184.	154.	338.	375.	55.	.000	.000
DEC 2	67	PHYS. MAT	7145.	4.01	11.4	169.	142.	310.	368.	55.	.000	.000
DEC 9	74	HARV. MAT	6334.	.47	11.4	181.	156.	337.	375.	55.	.000	.000

Press < ENTER > key to continue

Press Enter *or* Return

RUN NO. 1

CC PA 1986 Porrillo 1986

	PREDICTED	MEASURED
FLOWERING DATE	307	307
FIRST POD	312	0
FULL POD	319	0
PHYSIOL. MATURITY	334	341
POD YLD (KG/HA)	4417.00	4225.00
SEED YLD (KG/HA)	3368.00	3328.00
SHELLING PERCENTAGE	76.24	78.77
WT. PER SEED (G)	.198	.188
SEED NUMBER (SEED/M2)	1699.00	1768.00
SEEDS/POD	5.20	5.89
MAXIMUM LAI	6.10	6.61
BIOMASS (KG/HA) AT R8	6037.00	6231.00
STALK (KG/HA) AT R8	1532.00	1502.00
HARVEST INDEX	.558	.534

[Seed YLD and HI on DRYWEIGHT BASIS]

Press < ENTER > key to continue

Press Enter *or* Return

```
        Irrigation Summary
        ==================

 2 IRRIGATION APPLICATIONS @  1.00 EFFICIENCY.

CROP AGE    0   55
AMOUNT,mm  30.  25.

        DRY BEAN YIELD :  3367.8 KG/HA [ 3006.0 LBS/ACRE ]


 MORE SIMULATIONS ?
 Y OR N ? [DEFAULT = "Y"] ===>
```

Type: **N** and press **Enter** or **Return**

```
Stop - Program terminated.
```

Graphics Display

When you are running BEANGRO on a floppy-diskette system you will now have to replace the Program disk (No. 1) with the Graphics disk (No. 3). On a hard-disk system the program will immediately proceed with the graphics section of the model.

```
 Type Drive and path of graphics program ?
```

Type: **B:** if you are using a floppy-drive system, or enter the drive and path, e.g., **C:\BEANGRO**, if you are using a hard-disk system, and press **Enter** or **Return**

```
Which data drive contains the selected data?
```

Type: **B:** if you are using a floppy drive system, or enter the drive name, e.g., **C:**, if you are using a hard-disk system, and press **Enter** or **Return**

```
Graphics Options Available
[1] - CGA-LOW  - 320 x 200 pixels, 3 color graph
[2] - CGA-HIGH - 640 x 200 pixels, monochrome graph (HERCULES NOT AVAILABLE)
[3] - EGA-LOW  - 640 x 200 pixels, 6 color graph, requires EGA
[4] - EGA-MED  - 640 x 350 pixels, 3 color graph, requires EGA
[5] - EGA-HIGH - 640 x 350 pixels, 6 color graph, requires EGA
                 & 128k video memory

Enter graphics option  ?
```

Type: 1 or any other number which represents your system and press Enter or Return

```
Would you like to save disk drive and graphics option for future runs?
```

Type: Y if you want to save your setup on your floppy- or hard-disk system (or N) and press Enter or Return

```
SELECT GRAPH TYPE

1. Crop variables
2. Weather and soil variables
3. Nitrogen variables
4. Harvest variables
5. Graphical display of plant
6. Photosynthesis variables
0. Exit graph

Option (0,1,2,3,4,5 or 6)?
```

Type: 1 and press Enter or Return

```
READING DATA ... PLEASE WAIT!


FILE              RUN POINTS DOY
B:                  1    38   343
Do you want to plot field sample data points (Y/N)?
```

Type: Y (for this example) and press Enter or Return

```
VARIABLES AVAILABLE FOR GRAPHING ARE:        RUN# AVAILABLE FOR SELECTION ARE:
 1. Vegetative Growth Stage                     1. Porrillo 1986
 2. Leaf Area Index
 3. Number of Pods #/m2
 4. Stem Dry Weight (kg/ha)
 5. Seed Dry Weight (kg/ha)
 6. Leaf Dry Weight (kg/ha)
 7. Canopy Dry Weight (kg/ha)
 8. Pod Dry Weight (kg/ha)
 9. Shell Dry Weight (kg/ha)
10. Root Dry Weight (kg/ha)
11. Number of Seeds #/m2
12. Harvest Index (Seed/Top)
13. Shelling % (Seed/Pod*100)
14. Specific Leaf Area (cm2/g)
15. Seed Size (mg/seed)
              | use PAGE UP or PAGE DOWN to see more SELECTIONS |
16. Nitrogen % in Canopy
17. Relative Drought Stress Indicator
18. Root Length Density Level 1 cm/cm3
19. Root Length Density Level 2 cm/cm3
20. Root Length Density Level 3 cm/cm3
21. Root Length Density Level 4 cm/cm3
22. Root Length Density Level 5 cm/cm3
23. Root Length Density Level 6 cm/cm3
24. Root Length Density Level 7 cm/cm3
25. Root Length Density Level 8 cm/cm3

You may plot 1 to 6 lines with any combination of variables and run#
How many lines do you want to plot ?
```

Type: 4 (for this example) and press Enter or Return

```
LINE# 1 : ENTER VARIABLE#,RUN#
LINE# 2 : ENTER VARIABLE#,RUN#
LINE# 3 : ENTER VARIABLE#,RUN#
LINE# 4 : ENTER VARIABLE#,RUN#
```

Type: 4,1 and press Enter or Return
Type: 5,1 and press Enter or Return
Type: 6,1 and press Enter or Return
Type: 7,1 and press Enter or Return

```
Do you want to change X-axis, Y-axis or graphics display (Y/N)?
```

Type: N (for this example). This option allows you to change type of graphics display, scale of the X-axis and Y-axis and to switch between Day of the Year and Days After Planting for the X-axis.

An example of a BEANGRO output graph is displayed in Figure 1. If you would like a hard copy of the graph and have a printer available, press the <Shift>-<PrtSc> or <Print-

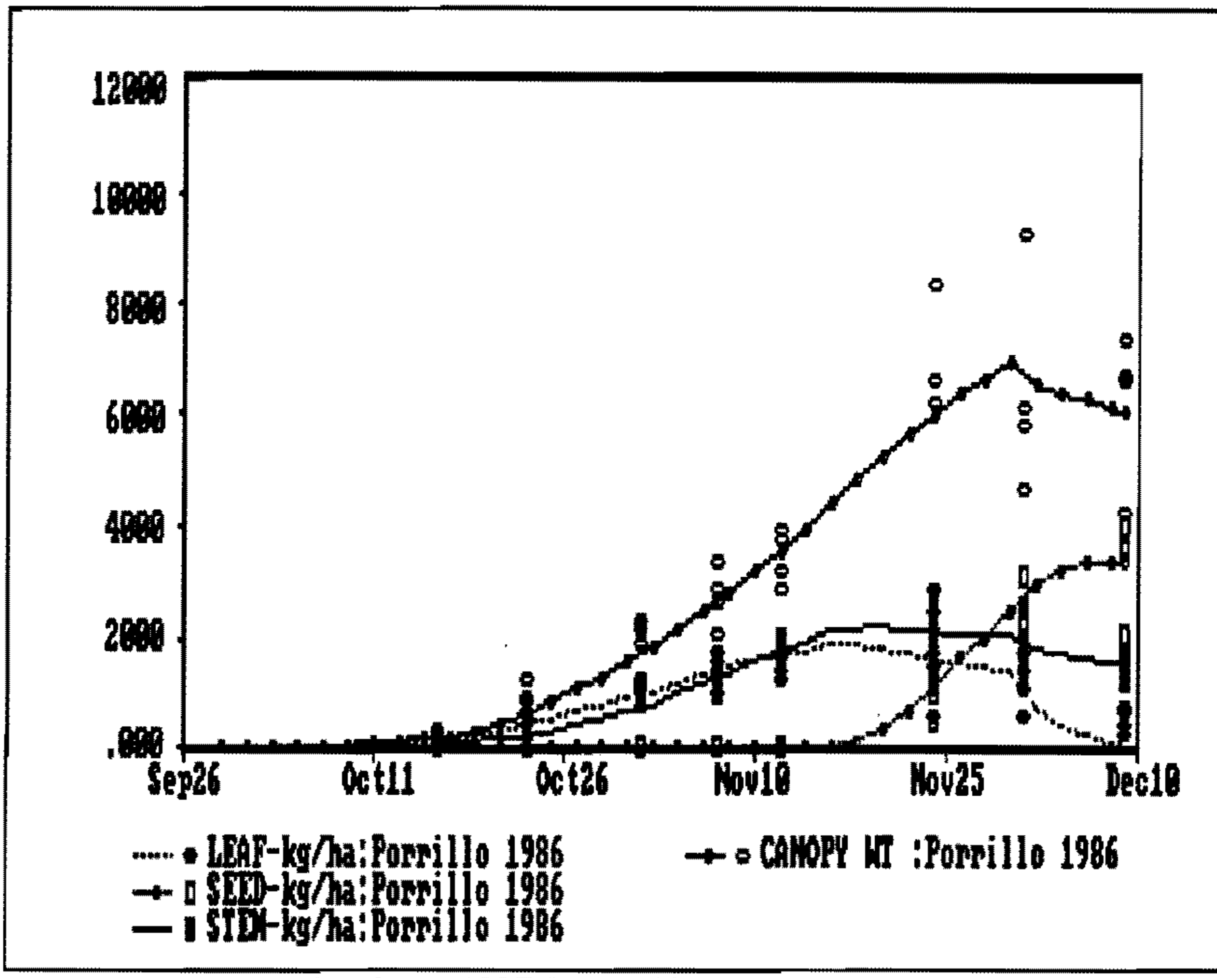

Figure 1. An Example of BEANGRO Graphics. Stem Weight, Seed Weight, Leaf Weight, and Canopy Weight as a Function of Day of the Year or Date.

Screen>. Remember to enter the GRAPHICS command before you start to run the simulation model. If the screen is copied to your printer without the plotted lines, you forgot to enter the GRAPHICS command while in DOS. <Shift>-<PrtSc> or <Print-Screen> does not work in Enhanced Graphics Mode. In this case, change the type of graphics display and select option 2, CGA-HIGH, by responding with Y to the prompt :"Do you want to change the X-axis, Y-axis or graphics display" after selecting the variables (see previous page). For certain laserprinters a special driver is required to make hard copies of your screen display.

More Graph Y/N?

Type: N (for this example) and press Enter or Return

```
SELECT GRAPH TYPE

1. Crop variables
2. Weather and soil variables
3. Nitrogen variables
4. Harvest variables
5. Graphical display of plant
6. Photosynthesis variables
0. Exit graph

Option (0,1,2,3,4 or 5)?
```

Type: **0** (to exit the graphics program) and press **Enter** or **Return**

Chapter 10
SENSITIVITY ANALYSIS

Besides running *case study experiments* or your own field experiments, there is also an option on the display to run *sensitivity analysis studies* with the model. After you have selected a particular experiment and treatment case study, enter option 1 when the computer prompts with:

```
WHAT WOULD YOU LIKE TO DO ?

0)  RUN SIMULATION.
1)  SELECT SENSITIVITY ANALYSIS OPTIONS.
2)  SELECT SIMULATION OUTPUT OPTIONS.

    CHOICE? [ DEFAULT = 0 ] ===>
```

The model will inform you that any time you change a particular parameter in the sensitivity analysis section, the model predictions will not correspond to the measured field data.

```
              MANAGEMENT / SENSITIVITY ANALYSIS.
              ==================================

     Following options are initially assigned values according
     to the case study and treatment selected.  With these
     default values you will be able to validate the simulation
     results.  You change the default values to evaluate alter-
     nate management strategies or make tactical decisions.
     If you choose not to change any of the current selections,
     press ENTER in response to questions.

     NOTE: THIS MESSAGE WILL NOT BE REPEATED

       Do you want to continue to display field measured data
       in the output table for comparison between simulated
       and measured data ?
       Y OR N ? [DEFAULT = "Y"]  ===>
```

The following options can currently be changed in the management or sensitivity analysis section of the model :

1. Cultivar

The cultivars currently available are listed in Table 2 and Table 20.

2. Simulation date : a. start of soil water balance simulation (no crop development and growth is simulated).
b. planting date.

3. Planting density : a. row spacing
b. plant spacing
c. row orientation (row orientation)

4. Irrigation management : a. rainfed
b. field or treatment schedule
c. stage specific autoirrigation as defined by the user depending on specified extractable soil water for a certain depth.
d. no water stress (soil water balance not simulated).

5. Soil series, type, or location:
The soil profiles currently defined in the model are listed in Table 14.

6. Weather for a certain site and year:
a. year
b. site
The weather data currently available are listed in Table 12.

7. Weather modification:
Each variable can be specified as either a relative or fixed change of the current value or set to a fixed value.
a. Carbon dioxide
b. Daylength
c. Photosynthetic Active Radiation
d. Precipitation
e. Solar Radiation
f. Maximum air temperature
g. Minimum air temperature

8. Photosynthesis / soil fertility
a. Growth reduction factor. This variable is used to reduce photosynthesis and biomass growth in the model. It accounts a growth reduction due to a poor soil fertility or due to a pest or disease which is present during the entire experiment
b. Switch for photosynthesis submodel (daily or hourly). The model has two options to calculate photosynthesis. The defaults calculates photosynthesis on an hourly level

through detailed light interception and canopy photosynthesis procedures. The second option only calculates photosynthesis once daily and is much simpler in approach.

9. Crop parameter selection

The current crop parameter file is listed in Table 21. The definitions of the crop parameters are given in Table 38.

10. Cultivar specific parameters

a. Select a different cultivar specific parameter file for calibration.
b. Interactively modify the cultivar specific parameters.

More detailed examples of sensitivity analysis runs with the model BEANGRO V1.01 and the other crop models have been presented in various publications (Boote et al. 1989b; Jones et al., 1991; Hoogenboom et al., 1988a).

The user can also modify the frequency at which variables are being stored in the output files and the types of files which are being saved. In general the more data are being stored, the slower the program will operate. The options are specified under "*Select Simulation Output Options*."

Chapter 11
PROCEDURES TO ADD NEW EXPERIMENTS FOR SIMULATION

Data Base Management System

There are two ways that input data files can be created for running BEANGRO V1.01. The files can be created manually using a file editor on the PC, or they can be created directly from the IBSNAT minimum data set after the experimental data have been entered on the forms supplied with IBSNAT Technical Report 1, 2nd edition (IBSNAT, 1986a),or 3rd edition (IBSNAT, 1988). Programs have been developed to enter the data into DSSAT Data Base Management System (DBMS) and retrieve the data into the proper IBSNAT file format (IBSNAT, 1986b, 1990a). All these programs are part of DSSAT (IBSNAT, 1989). Contact IBSNAT directly to order a copy of DSSAT or the software for minimum data set entry and data retrieval for the crop simulation models. The formats for all input and output files (FILE1 through FILE9 and FILEA, FILEB, and FILEC) are documented in Technical Report 5 (IBSNAT, 1986c, 1990a). IBSNAT has also defined standards on field and laboratory techniques for collecting minimum data sets (IBSNAT, 1990b).

Manual Creation of Files.

In creating each of the files indicated below, refer to IBSNAT Technical Report 5 Documentation for IBSNAT Crop Model Input & output Files, Version 1.1 (IBSNAT, 1990a) for the formats. The new files must use these formats or they will not work correctly.

1. Add a 3-line entry to file BNEXP.DIR to indicate to BEANGRO that a new experiment is available for simulation (See Table 11 where an example is highlighted).

2. If the experiment was performed during a new weather year or at a new site, create a new weather data file (i.e., CCPA0112.W86, see Table 13) and add one entry to file WTH.DIR to indicate its availability (See Table 12 where an example of a new entry is highlighted). Verify that weather data are available for the whole range of days for which you want to run your simulation because the model requires daily weather data. The model checks for missing and negative data entries (solar radiation and rainfall only) and will give the user a warning if the data do not match the required input formats.

3. If you want to use a soil type not found in the model's data base, add a new set of data to file SPROFILE.BN2 (Table 14). If the data for the soil at the experiment site is already in SPROFILE.BN2, then there is no need to add the soil again. Every soil should have a unique number in the file. IBSNAT has developed a

special soil data entry program to generate the parameters required for a particular soil type and this program is part of the DSSAT system (IBSNAT, 1989). The soil series name is needed to identify the particular soil profile you are defining and the soil family or soil taxonomy name, which currently only accept the American soil taxonomy convention, is used to calculate some of the input parameters. Minimum characteristics needed are : percentage sand, silt, clay, organic carbon, stoniness or rocks; and wet bulk density for each horizon. The pH value, percentage aluminum saturation, and nitrate and ammonia concentration are needed for future soil fertility aspects of the model. Some of these data can be obtained from the Soil Conservation Service (SCS) database in Lincoln, Nebraska (contact the authors of the model or IBSNAT to check if your particular soil type is available), your local or state SCS representative, or your local soil physics laboratory. The SMSS Project of SCS has collected soil profile information for many international sites, mainly in the lesser developed countries. This international soil database is currently distributed with DSSAT.

4. Create file ________.BN4 with initial soil nitrogen balance parameters, including weight of organic residue of previous crop, depth of surface residue incorporation, C:N ratio of surface residue, and dry weight of root residue (Table 15). Currently the BEANGRO model does not simulate the soil nitrogen balance, but this will be included in future versions.

5. Create file ________.BN5 with initial soil water conditions, initial NO_3 and NH_4 data for each treatment (Table 16). Note, if a sensitivity analysis is run and soil type is changed during simulation, the initial condition values will need to come from the soil profile data, not from FILE 5. The number of soil layers and their thicknesses must be exactly the same as those in the soil data file SPROFILE.BN2, for that soil; otherwise the model will abort and will give you an error message.

6. Create file ________.BN6 with all irrigation events for each treatment, including date and amount of irrigation for each irrigation event (Table 17). The last entry for each treatment is -1 for Day of Year and -1.0 for irrigation amount.

7. Create file ________.BN7 with all fertilizer application events for each treatment, including fertilizer application date, type and amount of fertilizer and depth of incorporations (Table 18). The last entry for each treatment is -1 for Day of Year and -1.0 for the other variables. Currently the BEANGRO model does not respond to fertilizer applications, but this will be included in future versions.

8. Create file ________.BN8 with a 2-line entry for management variables for each treatment. If there are 5 treatments, then there are 10 lines in this file. The file name designated by ________ should have 8 characters and be named according to Technical Report 5 (IBSNAT, 1990a), i.e., CCPA8629.BN8 is FILE 8 for institute CC (CIAT), site PA (Palmira, Colombia), year 86, and experiment 29 (Table 19).

Currently defined institute id's are given in the DSSAT User's Guide (IBSNAT, 1989).

9. If there is a new cultivar, determine genetic coefficient data and input into GENETICS.BN9 (Table 20). In diskette No. 2, the GENETICS.BN9 data file contains coefficients for many cultivars, ranging in adaptation from the tropics to temperate latitudes and climates. If you have a cultivar that is not included in the list, you should select a similar one from the current list defined in GENETICS.BN9. These cultivars are also presented in Table 2. The photoperiod response number is based on the photoperiod sensitivity and response as defined by CIAT. Both the photoperiod response and temperature response parameters are an indication of the adaptation of a cultivar to a certain environment. Lower photoperiod numbered cultivars are less sensitive to photoperiod, with 0 being almost insensitive. The highest photoperiod numbered cultivars are most sensitive to photoperiod, with 8 being the most sensitive. A detailed procedure to determine genetic coefficients for a new cultivar is described in Chapter 12.

10. For field comparisons, put treatment final yield data (averages) in file ________.BNA, 2 lines per treatment (Table 22). The following field measured variables are defined in file ________.BNA : seed dry yield (kg/ha), weight per seed (g/seed), number of seeds per m^2 (#/m^2), number of seeds per pod (#/pod), maximum LAI measured during the growing season (m^2/m^2), total above ground biomass at harvest (kg/ha), stem dry weight at harvest (kg/ha), flowering date (Day of Year), physiological maturity date (Day of Year), first pod date (Day of Year), full pod date (Day of Year), and pod dry yield (shells and seeds, kg/ha). Follow the format of the example shown in Table 22 to enter the data.

11. For graphical time-series analysis of simulated and measured crop growth and biomass data, put seasonal replicated growth and other measurements in file ________.BNB. An example of this file is on the data disk, No. 2, in file CCPA8629.BNB (Table 23). The order and the type of variables for file ________.BNB are given in the GLABEL.DAT file (Table 27). The first line defines the ID codes for institute, site, experiment number, year, and treatment. The explanation of these codes is given in Technical Report 5 (IBSNAT, 1990). The second line of each treatment defines which growth variables are present in the file. The numbers used in file ________.BNB should correspond to the numbers of the variables as defined in file GLABEL.DAT (Table 27). The first number on this second line defines the total number of field measured variables defined in file ________.BNB, excluding the first column which is the Day of Year. This variable is fixed, while the other variables can vary dependent upon the type of data collected during the growth-analysis experiment. The following lines contain the experimental data, starting with the Day of Year in the first column. Always keep at least two spaces between each column and align the data below the first input line. After you have entered all experimental data for a particular treatment, enter

a ▓ on the next line. Repeat the same setup for the other treatments of your experiment. More information is given in Technical Report 5 (IBSNAT, 1990a).

12. For graphical time-series analysis of simulated and measured soil water content, evapo-transpiration, and weather data, put seasonal replicated measured data in file ________.BNC. An example of this file is on the data disk, No. 2, in file CCPA8629.BNC (Table 24). No soil water content data were taken during the 1986 bean experiment, and therefore no measured field data are shown as an example in this file. The format for the data is identical as described for file ________.BNB. The order and the type of variables for file ________.BNC are given in the GLABEL2.DAT file (Table 28). The first line defines the ID codes for institute, site, experiment number, year, and treatment. The explanation of these codes is given in Technical Report 5 (IBSNAT, 1990a). The second line of each treatment defines which growth variables are present in the file. The numbers used in file ________.BNC should correspond to the numbers of the variables as defined in file GLABEL2.DAT (Table 28). The first number on this second line defines the total number of field measured variables defined in file ________.BNC, excluding the first column which is the Day of the Year. This variable is fixed, while the other variables can vary dependent upon the type of data collected during the growth analysis experiment. The following lines contain the observed data, starting with the Day of Year in the first column. Always keep at least two spaces between each column and align the data below the first input line. After you have entered all measured data for a particular treatment, enter a ▓ on the next line. Repeat the same setup for the other treatments of your experiment. Because of memory limitations, the graphics program can only handle a maximum of 50 dates per treatment.

13. For graphical time-series analysis of simulated and measured plant nitrogen concentrations, put seasonal replicated measured data in file ________.BND. An example of this file is on the data disk, No. 2, in file UFGA8601.BND (Table 25). No plant nitrogen data were taken during this 1986 bean experiment, and therefore no data are presented in this table. The order and the type of variables for file ________.BND are given in the GLABEL3.DAT file (Table 29). The first number on this second line defines the total number of field measured variables defined in file ________.BND, excluding the first column which is the Day of Year. This variable is fixed, while the other variables can vary dependent upon the type of data collected during the growth analysis experiment. The following lines contain the observed data, starting with the Day of Year in the first column. Always keep at least two spaces between each column and align the data below the first input line. After you have entered all measured data for a particular treatment, enter a ▓ on the next line. Repeat the same setup for the other treatments of your experiment. Because of memory limitations, the graphics program can only handle a maximum of 50 dates per treatment.

14. For graphical time-series analysis of simulated and measured light interception, canopy architecture, and photosynthesis data, put seasonal replicated measured data in file ________.BNP. An example of this file is on the data disk, No. 2, in file UFGA8601.BNP (Table 26). The order and the type of variables for file ________.BNP are given in the GLABELP.DAT file (Table 30). The first number on this second line defines the total number of field measured variables defined in file ________.BNP, excluding the first column which is the Day of Year. This variable is fixed, while the other variables can vary dependent upon the type of data collected during the growth analysis experiment. The following lines contain the observed data, starting with the Day of Year in the first column. Always keep at least two spaces between each column and align the data below the first input line. After you have entered all measured data for a particular treatment, enter a -1 on the next line. Repeat the same setup for the other treatments of your experiment. Because of memory limitations, the graphics program can only handle a maximum of 50 dates per treatment.

15. Crop-specific parameters are defined in file CROPPARM.BN0 (Table 21). The values of these parameters have been derived from the literature or carefully calibrated and, therefore, should not be changed. The definitions of the variables in CROPPARM.BN0 are given in Table 38.

After the files have been created properly, you can run BEANGRO for your experiment. The experiment, treatments, weather, soil, and cultivars will appear as choices in selecting simulation conditions for running both the case studies and the sensitivity-analysis section.

Sometimes the simulation model will be unable to predict your field-measured data and the graphics representation will show a poor fit to the data points. This might be caused by using a different cultivar which is not defined in file GENETICS.BN9, a soil type which is not defined in file SPROFILE.BN2, an experiment or set of treatments which cannot be simulated by the model because the options, i.e. fertility effects, are not available, or various other reasons. In most cases you can calibrate the model to your experimental data and carefully change a few parameters one at a time to properly fit your data. A detailed explanation of this calibration process is given in Chapter 12.

If you are trying to simulate two treatments which differ in fertility or soil pH or other aspects to which the model is not presently sensitive, you may wish to consider FORTRAN code changes to make the model sensitive to the desired feature. If you successfully make and validate such coding changes, we would appreciate receiving copies to review and consider for possible inclusion in future model versions.

Chapter 12
ESTIMATING GENETIC COEFFICIENTS FOR A NEW DRY BEAN VARIETY

Information on differences among bean genotypes are input to the model through file GENETICS.BN9 (Table 18). These coefficients allow a single bean crop growth model to predict differences in development, growth, and yield among cultivars when planted in the same environment. The genetic coefficients can be divided into those that relate to development, to vegetative growth, and to reproductive growth. Definitions of the coefficients are provided in Table 1, and values of the coefficients are given for thirteen cultivars in Table 2. (Hereafter the word "cultivar" will be used, it being understood that the material being calibrated might also be a bred line or land race).

Each cultivar is described in the GENETICS.BN9 file by seven lines of coefficients. As shown in Table 2, many of these coefficients are reasonably constant among the cultivars whereas others vary considerably (particularly those related to season length and yield components). One of the major questions asked by new users of the BEANGRO model is how to estimate these coefficients for a new cultivar. The following is a set of procedures to guide users of the model in estimating these genetic coefficients relative to experimental data collected on bean growth, phenology, and yield under field conditions.

Experimental Conditions and Measurements

Ideally, the experimental conditions for estimating genetic coefficients should be those allowing optimal growth, i.e., no water, nutrient, or pest stresses. Also, the set of data should include several planting dates or locations so that the data will include information or response under different daylengths, temperatures, and solar radiation levels. Currently, there are no genetic coefficients in the model that relate to differences among cultivars to responses to pest or nutrient stresses. When the experiment has encountered pest, nutrient, or water stresses, the procedures outlined below can still be used to estimate the coefficients, but the uncertainty in their values increases considerably.

The measurements that are needed to estimate the genetic coefficients are described in IBSNAT Technical Report No. 1 (IBSNAT, 1988, 1990b) and are referred to as the Minimum Data Set. Daily weather data are required. Soil properties are required, so the model can simulate the daily availability and distribution of water in the soil. Data on vegetative and reproductive growth and development are also needed. Data requirements are summarized in Table 3.

General Procedures

Once experimental data are available, one can use a trial and error approach to estimate the approximate values of genetic coefficients for a genotype that is not described in the

Table 1. Description of the Genetic Coefficients that Need to Be Estimated for a New Cultivar.

IVRGRP	Photoperiod response according to CIAT evaluations under 18 h artificially extended photoperiod.
IVRTEM	Temperature response class
CSDVAR	Threshold daylength for variety I, above which accumulation of the daylength accumulator proceeds at maximum rate.
CLDVAR	Threshold daylength for variety I, below which accumulation of the daylength accumulator proceeds at minimum rate.
THVAR	Photoperiod sensitivity defined as maximum reduction in developmental rate at day lengths greater than CLDVAR
PHTHRS	Threshold which must be crossed by either the night time accumulator or the physiological day accumulator in order for phenological event I to occur: 1 = Emergence (V-0) 2 = First full leaf (unifoliate) V-1 3 = End of juvenile phase 4 = Flowering induced (R0) 5 = First flower appearance (R1) 6 = First pod appearance (R3 = NPODO) 7 = First full pod (R4 = NR3) 8 = First full-sized seed appearance (R5) 9 = End of pod addition stops (NDSET) 10 = Physiological maturity (R7) 11 = Harvest maturity (R8). 12 = End of main stem (vegetative) growth 13 = End of leaf expansion (NDLEAF)
SHVAR	Maximum growth rate of an individual pod of variety I, if temperature is optimal, mg/(shell*day).
SDVAR	Maximum growth rate of an individual seed of variety I, if temperature is optimal, mg/(seed*day).
SDPDVAR	Number of seeds per pod.
PODVAR	Maximum rate of pod addition for variety I, number/day/m^2.
FLWMAX	Maximum rate of flower addition for variety I, number/day/m^2.
SDPRO	Fraction of seed weight which is protein.
TRIFOL	Number of trifoliolates per physiological day for variety I (maximum rate of V-stage formation).
SIZELF	The size of a normal upper node leaf of variety I used to normalize area per plant using ratio of SIZELF/SIZREF, cm^2/leaf.
SLAVAR	Specific leaf area (SLA) for new leaves during peak vegetative growth for cultivar I, cm^2/g.
LFMAX	Maximum leaf photosynthetic rate in saturated light, mg CO_2 m^{-2} s^{-1}.
XFRUIT	Reproductive partitioning coefficient determining maximum fraction of daily available photosynthesis available for seed and shell growth.
DETVEG	A switch which allows either indeterminate (0) or determinate (1) leaf area expansion (leaf thickening).
CNMOB	Fraction of available vegetative protein pool which is mobilized per physiological day for variety I.
THRESH	Maximum threshing percent allowed, seed weight in any given age class of fruits is not allowed to exceed this percentage of shell + seed weight.

Table 2. Sample Genetic Coefficients for Drybean Genotypes Adapted to Different Environments.

GENETIC COEFFICIENTS †

VARIETY	Porrillo Sintetico	BAT 477	Seafarer	C-20	BAT 881	ICTA Ostua	Rabia de Gato	Turbo III	Cuarentena	Carioca	Isabella	Manitou	ICA Linea 24
IVRGRP	03	01	01	01	01	01	03	03	01	01	01	01	08
IVRTEM	01	01	01	01	01	01	01	01	01	01	01	01	01
CSDVAR	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17	12.17
CLDVAR	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
THVAR	0.20	0.0	0.0	0.0	0.0	0.0	0.30	0.35	0.0	0.0	0.0	0.0	0.45
PHTHRS(1)	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
PHTHRS(2)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	05.0	5.0	04.0
PHTHRS(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHTHRS(4)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
PHTHRS(5)	27.0	26.0	21.0	28.0	28.0	25.0	20.0	28.0	23.0	25.0	21.0	24.0	28.0
PHTHRS(6)	4.0	3.0	03.0	3.0	3.0	3.0	4.0	3.0	3.0	4.0	02.5	07.0	03.0
PHTHRS(7)	11.0	10.0	11.0	11.0	11.0	10.0	10.0	9.0	12.0	11.0	8.0	13.0	06.0
PHTHRS(8)	12.0	11.0	12.0	12.0	12.0	12.0	12.0	12.0	13.0	12.0	9.0	14.0	08.0
PHTHRS(9)	17.0	15.0	22.0	25.0	15.0	19.0	25.0	19.0	17.0	17.0	15.0	18.0	12.0
PHTHRS(10)	26.0	26.0	32.0	35.0	26.0	30.0	30.0	30.0	27.0	31.0	32.0	38.0	29.0
PHTHRS(11)	9.0	10.0	9.0	9.0	9.0	9.0	8.0	9.0	9.0	9.0	9.0	09.0	09.0
PHTHRS(12)	12.0	10.0	7.0	7.0	10.0	0.0	0.0	0.0	9.0	12.0	0.0	00.0	0.0
PHTHRS(13)	22.0	22.0	15.0	20.0	22.0	22.0	5.0	5.0	22.0	22.0	22.0	15.0	25.0
SHVAR	45.0	45.0	35.0	39.0	27.0	28.0	50.0	21.0	40.0	30.0	48.0	50.0	56.0
SDVAR	20.0	20.0	17.0	17.0	16.0	15.0	20.0	18.0	30.0	15.0	19.0	20.0	19.0
SDPDVR	5.2	5.2	5.0	5.0	5.0	5.4	5.4	5.4	3.2	4.0	2.5	2.5	3.2
PODVAR	33.0	30.0	18.0	15.0	31.0	30.0	35.0	20.0	40.0	23.0	24.0	25.0	20.0
FLWMAX	66.0	60.0	36.0	30.0	62.0	60.0	70.0	40.0	80.0	46.0	60.0	50.0	40.0
SDPRO	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.235	0.235	0.235
TRIFOL	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
SIZELF	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0	133.0
SLAVAR	295.0	295.0	295.0	295.0	295.0	295.0	295.0	295.0	295.0	295.0	295.0	295.0	310.0
LFMAX	1.20	1.20	1.0	1.0	1.20	1.20	1.20	1.20	1.20	1.20	1.0	1.0	1.0
XFRT	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DETVEG	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CNMOB	0.040	0.040	0.040	0.050	0.040	0.050	0.050	0.050	0.040	0.040	0.050	0.050	0.050
THRESH	78.0	78.0	78.0	78.0	82.0	78.0	78.0	78.0	78.0	78.0	72.0	72.0	72.0

† The values given here are based on a number of different experiments; thus they may change as more data are acquired, and they are provided for guidance only.

genetics file (GENETICS.BN9). The general sequence of steps in applying this method is as follows:

1. Select initial genetic coefficient values for the genotype in question. Do this by first identifying in Table 2, a genotype similar to the genotype in question. Then, based on that genotype's coefficients and other available information, such as relative earliness or lateness, seed size, or photoperiod response, develop a list of "best guesses" for the new cultivar. To facilitate this exercise, blank columns are provided in Table 4, so that it may be used as a work sheet.

2. Create a new genotype entry into the GENETICS.BN9 file, entering the name of the genotype in question, and the selected initial coefficient values. You may use any file

Table 3. Summary of Minimum Data Requirements for Estimating the Genetic and Cultivar-specific Coefficients.

A. Weather

1. Daily Air Temperature; Maximum and Minimum, °C
2. Daily Rainfall, mm/day
3. Daily Solar Radiation, MJ/(m^2 day)

B. Management Data

(a) planting date
(b) row spacing, m
(c) plant population, pl/m^2
(d) cultivar name (and maturity group, if known).

C. Crop

1. Dates of:

(a) first true leaf, V-1
(b) 50% of plants with flower, anywhere on plant
(c) 50% of plants with pods just starting to expand, ≥ 1.0 cm in length, anywhere on plant.
(d) 50% of plants with last leaf expanded
(e) 50% of plants at physiological maturity (R-7, similar to soybean as defined by Fehr et al. (1971)).

2. Growth Analysis Data (at four or more dates in the season)

(a) total dry weight, g/m^2
(b) leaf biomass, g/m^2
(c) seed biomass, g/m^2
(d) number of pods/m^2
(e) leaf area index (LAI).

3. Final Harvest Data

(a) number of pods/m^2
(b) number of seeds/m^2
(c) above ground dry weight, g/m^2
(d) pod weight, g/m^2 (or seed weight, or both).

Table 4. Worksheet for Calibration of New Cultivars. See Table 2 for Coefficients of Additional Cultivars. Mean and Range of Genetic Coefficients are Shown for Certain Variables and Cultivars as an Example.

VARIETY	PORRILLO SINTET.	RABIA DE GATO	ISABELLA	SUGGESTED RANGE FOR CULTIVARS	NEW CULTIVARS			
Photoperiod response (CIAT)	03	03	01	1 - 8				
Temperature response	01	01	01	1				
Threshold, shortest photoperiod	12.17	12.17	12.17	12.17				
Threshold, longest photoperiod	18.00	18.00	18.00	18.00				
Photoperiod sensitivity	0.20	0.30	0.00	0.0 - 0.45				
PHTHRS(1) - Emergence	3.50	3.50	3.50	3.50				
PHTHRS(2) - V1	5.00	5.00	5.00	5.00				
PHTHRS(3) - End juvenile ph.	0.0	0.0	0.0	0.00				
PHTHRS(4) Flower initiation	5.00	5.00	5.00	5.00				
PHTHRS(5) - Flowering	27.0	20.0	21.0	18.0 - 30.0				
PHTHRS(6) - First pod	04.0	04.0	02.5	2.0 - 9.0				
PHTHRS(7) - First full pod	11.00	10.00	8.00	5.0 - 15.0				
PHTHRS(8) - Seed growth start	12.0	12.0	9.0	7.5 - 15.0				
PHTHRS(9) - End pod addition	17.00	25.00	15.00	10.0 - 24.0				
PHTHRS(10) - Phys. maturity	26.00	30.00	32.00	25.0 - 40.0				
PHTHRS(11) - Harv. maturity	9.00	8.00	9.00	9.00				
PHTHRS(12) - End MS growth	12.0	00.0	00.0	0.0 - 13.0				
PHTHRS(13) - End leaf expansion	22.0	05.0	22.0	05.0 - 28.0				
SHVAR - Shell growth rate	45.00	50.00	48.0	20.0 - 60.0				
SDVAR - Seed growth rate	20.0	20.0	19.0	15.0 - 30.0				
SDPDVR - Seeds/pod	5.2	5.4	2.5	3.0 - 5.5				
PODVAR - Pod appearance rate	33.0	35.0	24.0	15.0 - 35.0				
FLWMAX - Flower appear. rate	66.0	70.0	60	30.0 - 70.0				
SDPRO - Seed protein content	0.230	0.230	0.235	0.20 - 0.25				
TRIFOL - MS leaf appear. rate	0.400	0.400	0.400	0.400				
SIZELF - Index of leaf size	133.0	133.0	133.0	133				
SLAVAR - Index of SLA	295.00	295.00	295.00	270 - 310				
LFMAX - Leaf photosyn. rate	1.20	1.20	1.0	0.9 - 1.0				
XFRT - Reprod. partitioning coef.	1.00	1.00	1.0	1.0				
DETVEG - Deter./Indet. switch	1.0	1.0	1.0	1.0				
CNMOB - Nitrogen remobilization	0.040	0.050	0.050	0.03 - 0.06				
THRESH - Threshing percentage	78.0	78.0	72.0	72.0 - 82.0				

editor, being careful to save it as an ASCII file. Avoid using tab keys or alternatively, save the file using a NOTABS option.

3. Run the model for one location/treatment combination for which data are available.

4. Examine and <u>note</u> the goodness of fit between the predicted and measured variable, and decrease (or increase) the coefficient as described below, until the fit to observed data is satisfactory.

5. If more treatments/location combinations are available, note the values estimated for the first treatment/location combination, and then repeat (steps 3 and 4) for all other combinations. When all runs are complete, compute mean values for the genetic coefficients and enter these into the genetic coefficient file.

<u>Phenology of Common Bean</u>

Phenology of common bean is affected both by temperature and photoperiod. Most evidence suggests that there are cultivar differences in response to both factors (Laing et al., 1983; White and Laing, 1989), and these differences are thought to be related to the different gene pools recognized for common bean (Singh, 1989).

BEANGRO predicts phenology based on the concept of developmental rates which determine progress over time toward growth stages, which can be considered as critical developmental events. An event is considered to have occurred when the amount of developmental progress is equal to a previously specified threshold for that event.

In the absence of information on the underlying physiological processes controlling events such as flower initiation or onset of seed growth, the definition of units of developmental progress become arbitrary. One might try to define the developmental units in terms of cell numbers, concentration of a growth regulator, or other variable, but a particularly convenient approach is to use units of physiological time. This is because the threshold number of Developmental Units (DU) can be conceptualized as the minimum number of days or amount of time which must elapse before an event occurs, assuming a developmental rate of 1 DU per unit of time. The basic time clock of BEANGRO is in days, so rates in the model are given in DU per day. Algebraically this approach is equivalent to accumulation of photothermal time, but we find that the underlying concepts are more accurately represented by using the concept of rates of accumulation of developmental units.

In predicting cultivar differences in phenology, the critical parameters are the thresholds which determine whether a developmental process has reached completion and the sensitivity of the developmental process to environmental factors, usually temperature and photoperiod. The thresholds, parameters PHTHRS(1...13), are specified directly from the file GENETICS.BN9 (Table 18). Responses to environmental factors are calculated by assuming that the realized developmental rate for growth stage *i* (R_i) is a multiplicative function of the maximum developmental rate (M_i) and modifier functions representing temperature (T_i) and photoperiod (P_i),

$$R_i = M_i * T_i * P_i$$

The modifiers vary from 0 to 1, and the shape of the modifier functions is varied by changing parameters in GENETICS.BN9.

The basic temperature modifier assumes a trapezoidal response (Figure 2), and is evaluated on an hourly basis. These values are converted to the relative modifier T_i for a 24 h period. Differences in temperature responses among cultivars are poorly understood, so only two sets of responses are provided. These are selected by a switch, IVRTEM, which determines which set of response functions are used for a cultivar. For IVRTEM = 1, the responses represent those of a cultivar of Mesoamerican or Brazilian origin that is broadly adapted, and grows well in warmer bean production environments. The responses for IVRTEM = 1 are shown in Figure 2. For IVRTEM = 2, the responses are for highland adapted cultivars, which differ primarily from the previous group in being inhibited by temperatures over 20°C. If there is future evidence for additional temperature responses, higher values of the IVRTEM could be used providing that the responses are correctly specified in the file CROPPARM.BN0.

The photoperiod modifier, P_i, is varied as a function of daylength (Figure 3). P_i is equal to 1.0 when daylength is below CSDVAR, the threshold daylength below which there is no effect of photoperiod. For daylengths above CSDVAR, P_i decreases linearly unless the daylength exceeds CLDVAR, the threshold daylength which sets a limit above which the photoperiod inhibition proceeds at it's maximum effect. This maximum level is set by THVAR (righthand axis on Figure 3). To date, no cultivar differences in CSDVAR or CLDVAR have been used in GENETICS.BN9. It is suggested that all cultivar differences in photoperiod response be accounted for by varying THVAR. An exact relation between THVAR and the CIAT scale from 1 to 8 for photoperiod response (White and Laing, 1989) has not been developed. Any cultivar which is known to have a day-neutral response (CIAT score of 1) should be assigned a THVAR of 0, while any cultivar which is known to be extremely sensitive to photoperiod (CIAT score of 8) should be assigned a THVAR of 1. The CIAT photoperiod score is included for reference in the file GENETICS.BN9, but is not used for any computations in the model. If it is unknown, a value of 0 may be specified.

Diagnostic Key for Assigning Genetic Coefficients to Cultivars of Common Bean

To assign a bean cultivar appropriate genetic coefficients for BEANGRO Version 1.01, a key is provided for classifying cultivars in relation to the 12 cultivar whose coefficients

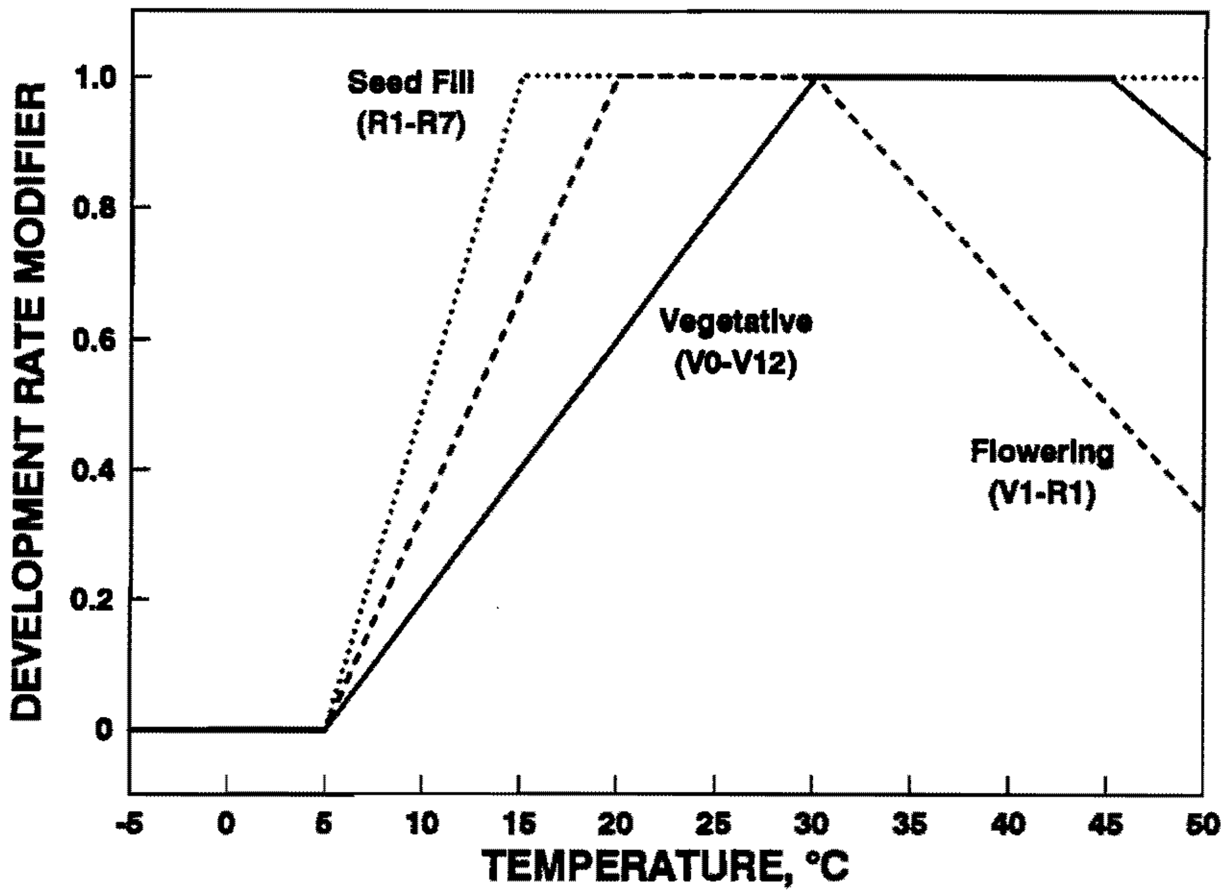

Figure 2. Temperature Modifier for Vegetative Development and Reproductive Development for Mesoamerican cultivars.

appear in the file GENETICS.BN9. The classification parallels the concepts of gene pools and races developed by S. Singh, P. Gepts, and D. Debouck in recent years. Growth habits are defined following the CIAT system where:

I	=	determinate bush
II	=	erect, indeterminate bush
III	=	prostrate, usually heavily branched, indeterminate bush
IV	=	climbers

BEANGRO has not been used to model climbing beans yet, so no cultivars are suggested for growth habit IV. Blank spaces for other types as well.

If information is not available on photoperiod response, the user may consult White and Laing (1989). CIAT maintains a database of photoperiod response, and will evaluate cultivars upon request. Research is currently underway between the University of Florida

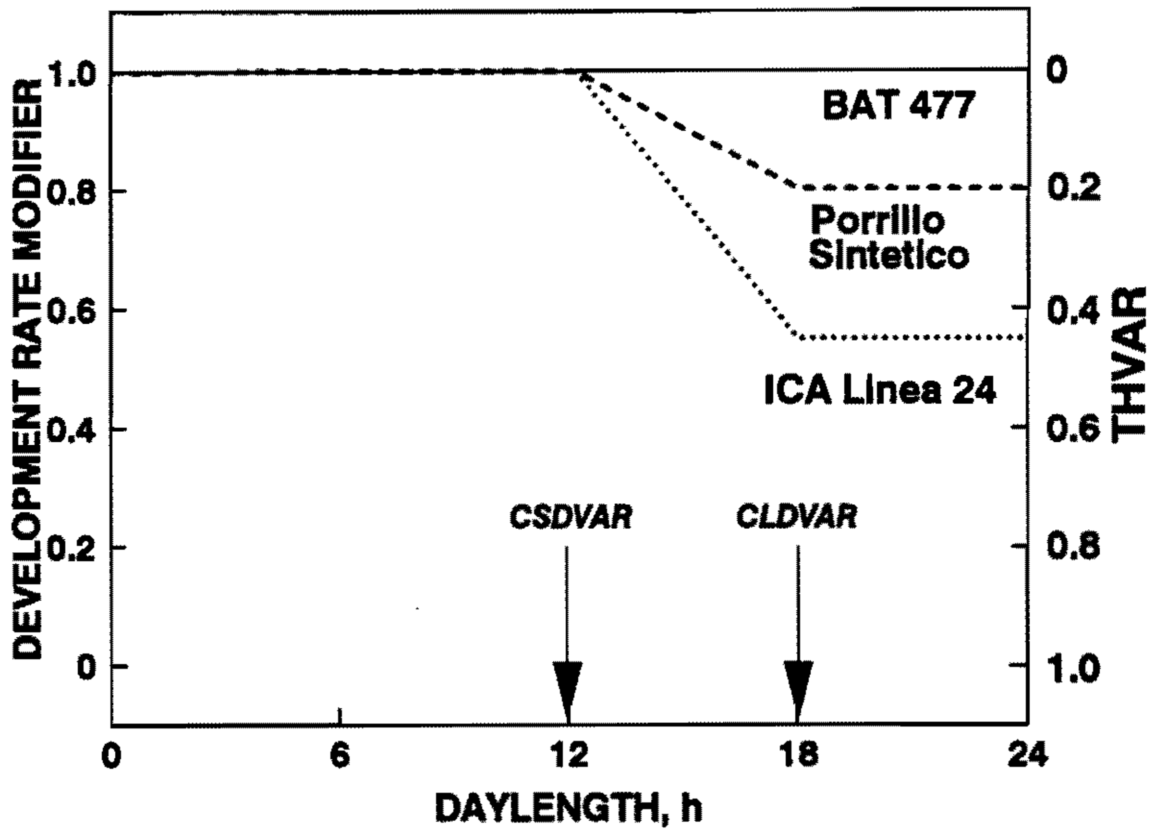

Figure 3. Photoperiod Modifier for Reproductive Development.

and CIAT, which should lead to clarification of relations between various genetic coefficients and seed size. Table 5 gives an overview of the current cultivars defined in BEANGRO and there associated grain types and growth habits. Names in parenthese indicate grain classes or well known cultivars; names written in **bold face** indicate cultivars calibrated in the file GENETICS.BN9 of BEANGRO Version 1.01.

Estimating Phenology Genetic Coefficients

Table 4 gives phenological thresholds (THVAR's) for three typical dry bean cultivars: Porrillo Sintetico, a small, black seeded line commonly grown in Central America; Rabia de Gato, an early maturing line from Guatemala; and Isabella, a large seed kidney bean. Table 4 provides estimates of the ranges of genetic coefficients which may be possible.

In calibrating the various coefficients for phenology, the user should first attempt to fit time to flowering by varying PHTHRS(5), the number of developmental units between flower

Table 5. Diagnostic Key for Assigment of Genetic Coefficients to Bean Cultivars.

Mesoamerican grain types (small reds, blacks, mulatinhos, navys)	
Lowland to mid-elevation adapted	
Growth habit Type I	**Seafarer**
Indeterminate habits	
Type II	
Day-neutral photoperiod response	**C-20, BAT 881**
Moderately photoperiod sensitive	**Porrillo Sintetico**
Type III	
Early-maturing	**Cuarentena**
	Rabia de Gato
Normal maturity	
Day-neutral photoperiod response	**Carioca**
	BAT 477
Moderately photoperiod sensitive	-
Type IV	-
Highland adapted (bayos, pintos, flor de mayos, great northerns)	
Type III	
Grown in the U.S.A./Europe	
Early-maturing	-
Normal-maturity	-
Grown in Mexican highlands or similar environments	
Type IV	-
Andean grain types	
Lowland to mid-elevation adapted (U.S.A./European cultivars)	
Type I/II (red kidney, sugars,large whites)	
Early maturing	**Isabella**
Normal maturity	**Manitou**
Type III	-
Highland adapted (large reds, red mottles...)	
Type I/II	
Early maturing	-
Normal maturing	**ICA Linea 24**
Type III	-
Type IV	-

initiation and first flower appearance. If different planting dates or locations are used, and the fitted and observed data show large discrepancies, then THVAR needs to adjusted to increase or decrease the sensitivity to photoperiod. Because actual flower initiation is very difficult to observe under field conditions a fixed number of 5 developmental units is used between the end of the juvenile phase and flower initiation (PHTHRS(4)). We recommend that users do not modify PHTHRS(4). During the first step of the calibration process an initial number for PHTHRS(5) can be selected from the values shown in Table 4. PHTHRS(5) can subsequently be adjusted in the sensitivity analysis section of the model until measured and observed flowering dates are similar. At the same time THVAR (sensitivity to photoperiod) can be modified if PHTHRS(5) exceeds the specified limits in Table 4.

Probably the most important coefficient is PHTHRS(10), because this determines the time from beginning flower (R1) to physiological maturity (R7). It is important because it sets the length of the reproductive period, and is a primary determinant of the seed filling period. Thus, it has a major impact on yield potential. In some cases it is difficult to predict harvest maturity of common bean because of the different standards and definitions used by various groups. In some cases beans also show regrowth during maturity which should not significantly affect final yield. Remember, before you simulate for other general situations, you should set the PHTHRS(10) to give you the normal expected maturity date for your selected cultivar. The values for PHTHRS(10) for some of the cultivars in the GENETICS.BN9 file are preliminary estimates, and may require adjustments for new locations.

If during the calibration to fit physiological maturity PHTHRS(10) reaches very small or very high values, it might indicate that the photoperiod sensitivity is set at the wrong value. In that case the photoperiod sensitivity should be adjusted and the process of fitting flowering and physiological maturity should be repeated. We recommend that you either increase or decrease THVAR slowly, while keeping both CSDVAR and CLDVAR constant.

For calibration of other thresholds versus field-observed phenological stages, follow the sequence of steps given in Table 6. The most critical one's to predict correctly are those determining onset of pod growth (R3) and onset of seed growth (R5). PHTHRS(6) controls the number of developmental units between start of flowering and beginning pod set. Furthermore, if one has field observed data, PHTHRS(6) can also be calibrated from the measured number of pods as a function of time. If the timing of the measured and simulated number of pods is different, especially the initial points, PHTHRS(6) requires an adjustment. Similarly PHTHRS(8) controls the number of developmental units between start of flowering and beginning of seed growth and determines the timing of the seed growth curve. Again seed growth data as a function of time can be used to adjust PHTHRS(8).

Table 6. Calibrating Important Genetic Coefficients by Comparison to Observed Phenological Date, Vegetative Traits, and Reproductive Traits.

OBSERVED VARIABLE	COEFFICIENT	STANDARD	RANGES
	Phenology & Development (developmental units †)		
Date of first flower (R1)	THVAR	0.20	0.0-0.45
Date of first flower (R1)	PHTHRS(5)	25.0	18.0-30.0
Date of beginning pod (R3)	PHTHRS(6)	4.0	2.0-9.0
Date of full-sized pod (R4)	PHTHRS(7)	11.0	5.0-15.0
Date of begin seed swell (R5)	PHTHRS(8)	12.0	7.5-15.0
Physiol. or harvest maturity	PHTHRS(10)	26.0	25.0-40.0
Time of last mainstem node ‡	PHTHRS(12)	12.0	0.0-13.0
Time of last leaf expansion ‡	PHTHRS(13)	22.0	5.0-28.0
	Reproductive Growth		
No. Seeds / No. Pods at final harvest sample	SDPDVR	5.2	3.0-5.5
Seed Wt. * 100 / Pod Wt. (Shelling %, final harvest)	THRESH	78.0	72.0-82.0
Dry Weight per Seed vs. Time or at final harvest sample §	SHVAR &	45.0	20.0-60.0
	SDVAR	20.0	15.0-30.0
No. of pods/m^2 vs. Time ¶	PODVAR	33.0	15.0-35.0
Shell Wt., g/m^2 vs. Time	SHVAR	(see above)	(see above)
Seed Wt., g/m^2 vs. Time	SDVAR,PHFAC3,LFMAX	(see above)	(see above)
Shelling % vs. Time	SDVAR,SHVAR,SDPDVR,THRESH	(see above)	(see above)
Harvest Index, Pod Wt. & Veg. Wt. vs Time #	XFRT	1.0	1.0
	Vegetative Growth		
Vstage vs. Time	TRIFOL	0.400	0.400
LAI vs. Time, prior to V8	SIZELF	133.0	133.0
SLA vs. Time	SLAVAR	295	270-310
Rate of Veg. Prot. Mobilization	CMMOB	0.04	0.03-0.06
D.M. Accum. Rate (Linear Phase)			
Genotypic Differences in	LFMAX	1.00	0.9-1.0
Soil Fertility Effects on D.M. Accum. Rate	PHFAC3 $	-	0.5-1.0

† Developmental units are equivalent to actual days if temperature and photoperiod are optimum for 24 hours per day.

‡ For climbing beans these values should be set greater than PHTHRS(10). Although many common bean cultivars are indeterminate, there is a point in the life cycle where rate of leaf appearance slows down dramatically and the apical mainstem aborts.

§ LNGSH and SHVAR together control the size of the pod which in turn allows a given size of seed to fill the cavity. LNGSH is at present a variable in CROPPARM.BND. If SDVAR is concurrently too low, seed size and the shelling percentage will not reach the desired value before the season ends. If SDVAR is too great, the shelling percentage and pod growth curve will reach a maximum (plateau) too early before harvest.

¶ Count only those pods which have seeds actively growing inside them. If you count every small and "stalled" pod, your pod number will be twice as great as simulated.

\# XFRT should only be set at a value smaller than 1.00 for climbing beans or indeterminate beans which show a very strong vegetative growth during maturity. In both cases the switch DETVEG should be set to 0.

$ The PHFAC3 coefficient is defined in the soil profile characterization file SPROFILE.BN2.

The variable PHTHRS(9) determines the number of developmental units until the last pod has been set and added, is normally defined as a fraction (0.66) of PHTHRS(10), i.e. physiological maturity.

<u>Estimating Vegetative Growth Coefficients</u>

Variation in parameters affecting vegetative growth is usually less important than for phenology coefficients. These vegetative growth coefficients should be adjusted only if adjustments to phenology and pod growth coefficients are insufficient to describe genotypic differences in growth and yield. TRIFOL can be varied until the V-stage vs. time is predicted, and SIZELF can be varied within certain limits to fit leaf area vs. time during early vegetative growth until V-8 stage occurs.

If data on LAI and leaf mass were collected, then you can compute the specific leaf area (SLA), and may wish to vary the SLAVAR to give a closer fit to SLA during peak vegetative growth. The CNMOB coefficient should be set to 0.04. This value can be changed if you have data on % N in leaf tissue vs. time.

The termination of the main stem apex can be observed from either field data or interpolation of the vegetative growth stages and can be used to set PHTHRS(12), i.e. end of main stem (vegetative) growth. PHTHRS(13) is the end of leaf expansion. Again this variable is very difficult to observe under field conditions, but can determined from the LAI curves. In the model the decrease in LAI caused by a relatively high leaf senescence rate and the termination of leaf growth is very sensitive to the value selected for PHTHRS(13).

<u>Reproductive Growth Coefficients</u>

These coefficients are important in defining the ability of the cultivar to develop a seed and pod load and in determining seed filling period duration and in determining final seed size, shelling %, and harvest index at final harvest. The coefficients SHVAR, SDVAR, SDPDVR, PODVAR, XFRT, and THRESH are among those influencing reproductive growth.

Seeds per pod (SDPDVR) and shelling percentage (THRESH) can be computed directly using harvest maturity data, provided no stress occurred, whereas the other coefficients (PODVAR, SHVAR, and SDVAR) are varied to fit pod numbers, shell weight, and seed weight versus time curves, respectively. If pod numbers versus time are too low, then PODVAR is increased until the rate of pod addition matches observed data, and vice versa. FLWMAX, i.e. flower appearance rate, is normally set double the value of PODVAR.

Following the calibration of PODVAR simulated shell and seed weight are compared with observed data. If simulated shell weight is too low, then SHVAR is increased until observed and simulated shell weight agree and vice versa. In this case SDVAR should be increased if simulated seed weight is lower than observed seed weight or if simulated single seed size is lower than observed single seed size. Changes in either SHVAR or SDVAR will affect both simulated shell and seed growth because of the carbohydrate supply/demand relationships in the model. One may have to adjust these coefficients iteratively until both shell and seed weights match observed data. Unlike in soybean, there are no set ratio's of SDVAR to SHVAR because of the differences in seed size and number of seeds per pod among common bean cultivars.

Another valuable aid to setting SHVAR and SDVAR is to compare simulated seed size (mg/seed) and shelling percentage to observed weight per seed and observed shelling percentage. If the slope of simulated seed size is too low increase SDVAR. If the slope of simulated seed size is too great and shelling percentage maximizes too soon, then reduce SDVAR. IF the slope of seed size is correct but seed size and shelling percentage reach a plateau and seeds fail to achieve final seed size, then increase SHVAR. In this case the seed size is limited by the pod cavity.

Other Genetic Coefficients in GENETICS.BN9

The other coefficients should simply be copied from another cultivar, which assumes that these really vary only slightly among cultivars.

Biomass Growth Rate

In some cases, we have found the simulated top growth is significantly greater than observed top dry weight during the linear phase of crop growth (mid-season, full canopy, but prior to the middle of seed fill). This may occur even without water stress conditions. Under these situations, we have concluded that factors of soil fertility, pH, and soil-borne pests such as nematodes, maybe causing reductions in photosynthesis or changes in partitioning, or both. In the soil profile defined for the site, you will find a coefficient (PHFAC3) that can be adjusted to increase or reduce the crop growth rate during the linear phase to fit the observed early season biomass accumulation prior to mid-seedfill. Make changes to PHFAC3 only after estimating the other genetic coefficients, because life cycle length and pod growth traits have an impact on the rate of dry matter accumulation. For Florida soils we have used a PHFAC3 of 0.84, but for soybean we have observed values up to 1.0 for Iowa and Illinois soils which presumably are more fertile and have few pests. For peanuts grown on infertile soils in India, we have found PHFAC3 values as low as 0.60 to 0.70. (Note: Values of 1.00 for PHFAC3 in the soil profile file SPROFILE.BN2 are merely default values given by the DSSAT soil retrieval program.) Users should begin with PHFAC3 set at 1.00 and subsequently calibrate their own PHFAC3 in the range 0.50 to 1.00 to match the slope of crop dry weight accumulation. If you have drought stress, do not vary PHFAC3 because drought will override any effects. Even for well-watered experiments, you should run subsequent experiments to verify the stability of the selected value for PHFAC3 in a second year or time of year. (Current efforts are being made to include soil nutrient effects explicitly in our GRO models as well as effects of certain nematodes.)

In rare situations where you have two cultivars growing in the same field environment, and one has a steeper slope of dry matter accumulation (not caused by stand or fertility differences), you may wish to vary the LFMAX among the cultivars to best fit the slope of total crop dry matter accumulation. Use caution in varying LFMAX; always change the PHFAC3 first if you have single cultivar experiments or the cultivars are not grown in the same field in the same growing season.

The LFMAX coefficient serves several functions. First LFMAX allows one to simulate differences in biomass accumulation among bean genotypes as described above. Secondly, it allows one to consider meaningful leaf level inputs into the model. We measured values of light-saturated leaf photosynthesis close to 1.00 mg m^{-2} s^{-1} for the bean cultivars in the 1986 Gainesville studies. Use of LFMAX = 1.00 gives approximately the correct magnitude of biomass accumulation. Lastly, a LFMAX coefficient was necessary to allow us to simulate bean, soybean, and peanut grown on the same soils (with the same PHFAC3 = 0.84). Peanut has a crop growth rate (CGR) about 40 % greater than that of soybean and bean and has a higher LFMAX. Published literature indicates that peanut has higher light-saturated leaf photosynthesis.

Chapter 13
MODEL APPLICATIONS

Although this is the first official release version of BEANGRO, the model is already being used in several projects. In Guatemala, a U.S. A.I.D. project has been initiated in collaboration with the Instituto de Ciencia y Tecnologia Agricolas (ICTA) to study bean farming systems in Jutiapa, a region in Southeastern Guatemala. This study involves the calibration and validation of BEANGRO and two other IBSNAT models, CERES-Maize and CERES-Sorghum, and the construction of models of representative farming systems (Hoogenboom and Thornton, 1990; Hoogenboom et al., 1990a; Thornton and Hoogenboom, 1990).

The University of Florida, in collaboration with the University of Puerto Rico, is developing a user-oriented regional agricultural planning, information, and decision support system named AEGIS Agricultural and Environmental Geographic Information System (Lal et al., 1990). BEANGRO will be used in this project to predict potential bean production in Puerto Rico.

In USDA Project W-150 entitled "Genetic Improvement of Beans (*Phaseolus vulgaris* L.) for Yield, Pest Resistance and Food Value," an International Dry Bean Modeling Nursery is being established at several sites in Canada, U.S.A. and Central and South America. The objective is to grow the same cultivars at all locations and to study the potential of using BEANGRO as a breeding tool to help better understand the Genotype * Environment interaction (Hoogenboom et al., 1990e).

The model can also be used to study the potential impact of global climate change on agricultural production. Previous investigations with SOYGRO have shown that there is great potential for using crop models in this area (Boote et al., 1989b; Curry et al., 1990a,1990b).

Collaboration currently also exists with Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in Costa Rica and bean researchers in Brazil and Rwanda.

Users are also encouraged to contact IBSNAT and to subscribe to Agrotechnology Transfer, in which many articles are published related to IBSNAT and the crop models, see for instance a recent article on general applications of BEANGRO (White and Hoogenboom, 1991).

We hope that our existing network of bean researchers and BEANGRO users will expand as a result of the release of BEANGRO Version 1.01. Please contact Dr. Hoogenboom at the University of Georgia or Dr. White at CIAT if you are interested in sharing your results and experience. We look forward to receiving any comments about BEANGRO.

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Appendix A
DIRECTORY LISTING OF DISTRIBUTION DISKETTES

Program Disk

Table 7. Directory of BEANGRO V1.01 disk 1: "*Program Disk.*"

BEANGRO	BAT	13	10-01-91	1:01a
BGRO	BAT	68	10-01-91	1:01a
GRO	EXE	165970	10-01-91	1:01a

Data Disk

Table 8. Directory of BEANGRO V1.01 disk 2: "*Data Disk.*"

BNEXP	DIR	893	10-01-91	1:01a
WTH	DIR	540	10-01-91	1:01a
SPROFILE	BN2	37040	10-01-91	1:01a
CROPPARM	BN0	5188	10-01-91	1:01a
GENETICS	BN9	7325	10-01-91	1:01a
CCPA0112	W86	13576	10-01-91	1:01a
CCPA0112	W87	13576	10-01-91	1:01a
CCPA8629	BN5	5365	10-01-91	1:01a
CCPA8629	BN6	625	10-01-91	1:01a
CCPA8629	BN7	674	10-01-91	1:01a
CCPA8629	BN8	1561	10-01-91	1:01a
CCPA8629	BNA	1129	10-01-91	1:01a
CCPA8629	BNB	35053	10-01-91	1:01a
CCPA8629	BNC	829	10-01-91	1:01a
CCPA8629	BNP	829	10-01-91	1:01a
EBGO0112	W87	13576	10-01-91	1:01a
IGQU0409	W89	8132	10-01-91	1:01a
IGQU8903	BN4	111	10-01-91	1:01a
IGQU8903	BN5	786	10-01-91	1:01a
IGQU8903	BN6	78	10-01-91	1:01a
IGQU8903	BN7	174	10-01-91	1:01a
IGQU8903	BN8	391	10-01-91	1:01a
IGQU8903	BNA	264	10-01-91	1:01a
IGQU8903	BNB	4067	10-01-91	1:01a
UBKA0508	W86	9136	10-01-91	1:01a
UFGA0112	W85	16131	10-01-91	1:01a
UFGA0112	W86	20516	10-01-91	1:01a
UFGA8501	BN5	2665	10-01-91	1:01a
UFGA8501	BN6	729	10-01-91	1:01a
UFGA8501	BN8	1041	10-01-91	1:01a
UFGA8501	BNA	753	10-01-91	1:01a
UFGA8501	BNB	6597	10-01-91	1:01a
UFGA8601	BN5	3331	10-01-91	1:01a
UFGA8601	BN6	3537	10-01-91	1:01a
UFGA8601	BN8	1361	10-01-91	1:01a
UFGA8601	BNA	941	10-01-91	1:01a
UFGA8601	BNB	14206	10-01-91	1:01a
UFGA8601	BNC	691	10-01-91	1:01a
UFGA8601	BND	691	10-01-91	1:01a
UFGA8601	BNP	1515	10-01-91	1:01a
INTRO	DAT	1914	10-01-91	1:01a
SIM	DIR	145	10-01-91	1:01a
OUT1	BN	4468	10-01-91	1:01a
OUT2	BN	7590	10-01-91	1:01a
OUT3	BN	9580	10-01-91	1:01a
OUT4	BN	2061	10-01-91	1:01a
OUT5	BN	516	10-01-91	1:01a
OUT8	BN	477	10-01-91	1:01a
OUT9	BN	468	10-01-91	1:01a
OUTP	BN	4550	10-01-91	1:01a

Graphics Disk

Table 9. Directory of BEANGRO V1.01 disk 3: "*Graphics Disk.*"

BEANGRO	BAT	13	10-01-91	1:01a
BGRO	BAT	68	10-01-91	1:01a
BRUN45	EXE	77440	10-01-91	1:01a
GLABEL	DAT	1032	10-01-91	1:01a
GLABEL2	DAT	1026	10-01-91	1:01a
GLABEL3	DAT	169	10-01-91	1:01a
GLABEL4	DAT	498	10-01-91	1:01a
GLABELP	DAT	587	10-01-91	1:01a
GRAPH	BAT	27	10-01-91	1:01a
GRPH	EXE	52310	10-01-91	1:01a
HVGRF	EXE	16510	10-01-91	1:01a
LL1	LEV	909	10-01-91	1:01a
LLB	LEV	1037	10-01-91	1:01a
MAIN	EXE	11764	10-01-91	1:01a
N2	PLT	607	10-01-91	1:01a
N4	PLT	700	10-01-91	1:01a
NEWPLT	EXE	93712	10-01-91	1:01a
RLB	LEV	1040	10-01-91	1:01a
SOYV2	PLT	3732	10-01-91	1:01a

Table 10. Directory of BEANGRO V1.01 disk 4: "*Source Code.*"

GROOBJ		363	10-01-91	1:01a
COMPILE	BAT	31	10-01-91	1:01a
GROLINK	BAT	62	10-01-91	1:01a
CANOPG	FOR	1971	10-01-91	1:01a
CANOPY	FOR	1235	10-01-91	1:01a
CLEAR	FOR	159	10-01-91	1:01a
COMGRO	DAT	7242	10-01-91	1:01a
COMIO	DAT	2896	10-01-91	1:01a
COMSOI	DAT	1228	10-01-91	1:01a
ETRTIO	FOR	2977	10-01-91	1:01a
FRACD	FOR	1007	10-01-91	1:01a
FREEZE	FOR	1254	10-01-91	1:01a
GPHEN	FOR	8392	10-01-91	1:01a
GRO	FOR	7768	10-01-91	1:01a
GROW	FOR	2624	10-01-91	1:01a
GROWI	FOR	855	10-01-91	1:01a
HEDGE	FOR	8387	10-01-91	1:01a
HRAD	FOR	3180	10-01-91	1:01a
HTEMP	FOR	1964	10-01-91	1:01a
IDCROP	FOR	1624	10-01-91	1:01a
IDWTH	FOR	2198	10-01-91	1:01a
INPHEN	FOR	5545	10-01-91	1:01a
INSOIL	FOR	4315	10-01-91	1:01a
INTRO	FOR	393	10-01-91	1:01a
INVAR	FOR	8035	10-01-91	1:01a
IPCROP	FOR	6490	10-01-91	1:01a
IPEXP	FOR	8679	10-01-91	1:01a
IPFERT	FOR	1820	10-01-91	1:01a
IPFREQ	FOR	4471	10-01-91	1:01a
IPSENS	FOR	12333	10-01-91	1:01a
IPSOIL	FOR	3675	10-01-91	1:01a
IPTRT	FOR	1772	10-01-91	1:01a
IPVAR	FOR	3824	10-01-91	1:01a
IPWTH	FOR	5355	10-01-91	1:01a
IRRIG	FOR	3135	10-01-91	1:01a
JULIAN	FOR	911	10-01-91	1:01a
LFCHAR	FOR	9042	10-01-91	1:01a
NAILUJ	FOR	504	10-01-91	1:01a
OPECHO	FOR	4639	10-01-91	1:01a
OPHARV	FOR	14479	10-01-91	1:01a
OPHEAD	FOR	1733	10-01-91	1:01a
OPSEAS	FOR	10895	10-01-91	1:01a
OPWTH	FOR	4253	10-01-91	1:01a
PHOTIN	FOR	820	10-01-91	1:01a
PHOTO	FOR	5478	10-01-91	1:01a
PHOTOD	FOR	3270	10-01-91	1:01a
PHOTOL	FOR	791	10-01-91	1:01a
PLANT	FOR	9172	10-01-91	1:01a
PODS	FOR	20407	10-01-91	1:01a
ROOTS	FOR	1284	10-01-91	1:01a
SENES	FOR	3490	10-01-91	1:01a
SOLCON	FOR	930	10-01-91	1:01a
SUNRIS	FOR	1881	10-01-91	1:01a
TABEX	FOR	382	10-01-91	1:01a
VEGGR	FOR	7973	10-01-91	1:01a
VERIFY	FOR	2288	10-01-91	1:01a
WATBAL	FOR	16953	10-01-91	1:01a
WEATHER	FOR	1254	10-01-91	1:01a
WTHMDI	FOR	8228	10-01-91	1:01a
WTHMOD	FOR	3572	10-01-91	1:01a

Appendix B
INPUT FILES

Experimental Directory

Table 11. File "*BNEXP.DIR.*"

```
CCPA8629 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES   CCPA0112.W86 SPROFILE.BN2
CCPA8629.BN4 CCPA8629.BN5 CCPA8629.BN6 CCPA8629.BN7 CCPA8629.BN8 GENETICS.BN9
CCPA8629.BNA CCPA8629.BNB OUT1.BN OUT2.BN OUT3.BN OUT4.BN OUT5.BN
IGQU8903 ICTA-OSTUA,RABIA DE GATO,TURBO-III;1989  IGQU0409.W89 SPROFILE.BN2
IGQU8903.BN4 IGQU8903.BN5 IGQU8903.BN6 IGQU8903.BN7 IGQU8903.BN8 GENETICS.BN9
IGQU8903.BNA IGQU8903.BNB OUT1.BN OUT2.BN OUT3.BN OUT4.BN OUT5.BN
UFGA8501 4 CULTIVARS, IRR. & NONIRRIGATED         UFGA0112.W85 SPROFILE.BN2
UFGA8501.BN4 UFGA8501.BN5 UFGA8501.BN6 UFGA8501.BN7 UFGA8501.BN8 GENETICS.BN9
UFGA8501.BNA UFGA8501.BNB OUT1.BN OUT2.BN OUT3.BN OUT4.BN OUT5.BN
UFGA8601 2 CULTIVARS, 5 IRRIGATION TREATMENTS     UFGA0112.W86 SPROFILE.BN2
UFGA8601.BN4 UFGA8601.BN5 UFGA8601.BN6 UFGA8601.BN7 UFGA8601.BN8 GENETICS.BN9
UFGA8601.BNA UFGA8601.BNB OUT1.BN OUT2.BN OUT3.BN OUT4.BN OUT5.BN
```

Weather Directory

Table 12. File "*WTH.DIR.*"

CCPA	CIAT, PALMIRA, COLOMBIA	1986	01-01-86	12-31-86	CCPA0112.W86
CCPA	CIAT, PALMIRA, COLOMBIA	1987	01-01-87	12-31-87	CCPA0112.W87
EBGO	CNPAF, GOIANIA, BRAZIL	1987	01-01-87	12-31-87	EBGO0112.W87
IGQU	QUEZADA, GUATEMALA	1989	04-01-89	09-30-89	IGQU0409.W89
UBKA	KAJONDI FARM, BURUNDI	1986	05-01-86	12-31-86	UBKA0508.W86
UFGA	GAINESVILLE, FLORIDA, USA	1985	01-01-85	12-31-85	UFGA0112.W85
UFGA	GAINESVILLE, FLORIDA, USA	1986	01-01-86	12-31-86	UFGA0112.W86

FILE1 - Daily Weather Data

Table 13. File "*CCPA1012.W86*" (Data for only the first 50 days are shown).

```
CCPA   3.48  76.37 12.07  0.00         XLAT, XLONG, PARFAC, PARDAT
CCPA 86   1 17.60  29.0  18.1   0.0
CCPA 86   2 20.90  30.0  16.5   0.0
CCPA 86   3 18.20  30.0  19.0   0.0
CCPA 86   4 17.90  29.8  18.5   0.0
CCPA 86   5 16.90  28.5  19.2  18.1
CCPA 86   6 17.80  28.2  18.3   0.0
CCPA 86   7 17.40  29.0  19.0   0.0
CCPA 86   8 18.50  30.0  19.0   0.0
CCPA 86   9 19.80  30.8  20.2   0.0
CCPA 86  10 19.30  30.2  19.5   0.0
CCPA 86  11 19.20  31.0  20.0   0.0
CCPA 86  12 18.80  30.8  19.5   0.0
CCPA 86  13 17.70  30.0  19.5   0.0
CCPA 86  14 17.40  31.0  19.6   2.7
CCPA 86  15 20.70  30.0  19.0   9.9
CCPA 86  16 11.70  25.5  20.2   0.0
CCPA 86  17 18.80  29.3  20.0   4.7
CCPA 86  18 13.80  28.0  19.5   0.0
CCPA 86  19 15.20  28.5  19.5   0.0
CCPA 86  20 13.80  28.0  20.0   2.3
CCPA 86  21 20.40  30.0  20.2   0.0
CCPA 86  22 19.10  30.5  20.4   0.0
CCPA 86  23 20.80  30.4  20.2   0.0
CCPA 86  24 14.20  26.0  18.9  22.0
CCPA 86  25 21.00  30.0  17.3   0.0
CCPA 86  26 14.80  29.7  19.8   5.8
CCPA 86  27  9.50  23.4  19.2   0.4
CCPA 86  28 20.70  28.6  16.5   0.0
CCPA 86  29 21.60  29.6  17.5   0.0
CCPA 86  30 20.20  30.7  18.5   0.0
CCPA 86  31 11.50  26.6  20.3   1.0
CCPA 86  32 19.90  30.0  17.0   0.0
CCPA 86  33 15.30  29.0  18.0   0.0
CCPA 86  34 15.00  28.0  19.5   0.0
CCPA 86  35 16.00  27.5  19.0   0.0
CCPA 86  36 19.80  29.0  19.4   0.0
CCPA 86  37 20.80  30.1  18.5   0.0
CCPA 86  38 20.50  30.2  19.5   0.0
CCPA 86  39 20.70  30.0  18.2   0.0
CCPA 86  40 17.90  29.2  18.0   0.0
CCPA 86  41 14.50  26.4  19.3   0.0
CCPA 86  42 21.20  31.0  18.4  14.8
CCPA 86  43 14.50  27.0  18.5   7.9
CCPA 86  44 18.40  27.0  18.5   1.9
CCPA 86  45 21.20  28.5  19.5   5.9
CCPA 86  46 20.30  29.0  19.0   0.0
CCPA 86  47 19.80  29.0  19.0  11.8
CCPA 86  48  8.10  23.0  18.8  11.6
CCPA 86  49 15.60  27.1  19.0   0.0
CCPA 86  50 23.80  29.5  16.8   0.0
```

Table 14. File *"SPROFILE.BN2."*

```
01               DEEP SILTY CLAY
  .11  6.00      .30  85.00    6.9  13.9 1.0  1.32E-03   32.5  6.67    .04 1.00
  10.    .513    .680    .760    .680  1.000  1.35  1.74  2.5  3.3  6.5  .00
  15.    .513    .679    .759    .679   .819  1.36  1.66  2.4  3.2  6.5  .00
  15.    .514    .679    .759    .679   .607  1.36  1.45  2.2  3.0  6.5  .00
  15.    .514    .679    .759    .679   .607  1.36  1.45  2.2  3.0  6.5  .00
  30.    .516    .677    .757    .677   .368  1.37  1.09  2.0  2.6  6.5  .00
  30.    .519    .675    .755    .675   .202  1.38   .65  1.7  2.2  6.5  .00
  30.    .521    .674    .754    .674   .111  1.38   .29  1.4  1.8  6.5  .00
  30.    .522    .673    .753    .673   .061  1.39   .09  1.1  1.3  6.5  .00
  30.    .522    .673    .753    .673   .033  1.39   .01   .8   .9  6.5  .00
  -1.    .00     .00     .00     .00    .00    .00   .00   .0   .0   .0  .00
02               MEDIUM SILTY CLAY
  .11  6.00      .20  87.00    6.9  13.9 1.0  1.32E-03   32.5  6.67    .04 1.00
  10.    .513    .680    .760    .680  1.000  1.35  1.74  2.5  3.3  6.5  .00
  15.    .513    .679    .759    .679   .819  1.36  1.66  2.4  3.2  6.5  .00
  15.    .514    .679    .759    .679   .607  1.36  1.45  2.2  3.0  6.5  .00
  15.    .516    .677    .757    .677   .407  1.37  1.12  2.0  2.7  6.5  .00
  15.    .516    .677    .757    .677   .407  1.37  1.12  2.0  2.7  6.5  .00
  30.    .518    .676    .756    .676   .247  1.37   .73  1.8  2.3  6.5  .00
  30.    .520    .674    .754    .674   .135  1.38   .37  1.5  1.9  6.5  .00
  -1.    .00     .00     .00     .00    .00    .00   .00   .0   .0   .0  .00
03               SHALLOW SILTY CLAY
  .11  6.00      .10  89.00    6.9  13.9 1.0  1.32E-03   32.5  6.67    .04 1.00
  10.    .513    .680    .760    .680  1.000  1.35  1.74  2.5  3.3  6.5  .00
  10.    .513    .679    .759    .679   .819  1.36  1.66  2.4  3.2  6.5  .00
  10.    .514    .679    .759    .679   .607  1.36  1.45  2.2  3.0  6.5  .00
  10.    .516    .677    .757    .677   .449  1.36  1.16  2.1  2.7  6.5  .00
  15.    .516    .677    .757    .677   .449  1.36  1.16  2.1  2.7  6.5  .00
  -1.    .00     .00     .00     .00    .00    .00   .00   .0   .0   .0  .00
04               DEEP SILT LOAM
  .12  6.00      .40  77.00    6.9  13.9 1.0  1.32E-03   93.1  6.67    .04 1.00
  10.    .106    .262    .362    .262  1.000  1.37  1.16  2.5  3.3  6.5  .00
  15.    .106    .262    .362    .262   .819  1.37  1.10  2.4  3.2  6.5  .00
  15.    .107    .262    .362    .262   .607  1.37   .97  2.2  3.0  6.5  .00
  15.    .107    .262    .362    .262   .607  1.37   .97  2.2  3.0  6.5  .00
  30.    .108    .261    .361    .261   .368  1.38   .72  2.0  2.6  6.5  .00
  30.    .110    .260    .360    .260   .202  1.38   .43  1.7  2.2  6.5  .00
  30.    .111    .259    .359    .259   .111  1.39   .20  1.4  1.8  6.5  .00
  30.    .112    .258    .358    .258   .061  1.39   .06  1.1  1.3  6.5  .00
  30.    .112    .258    .358    .258   .033  1.39   .01   .8   .9  6.5  .00
  -1.    .00     .00     .00     .00    .00    .00   .00   .0   .0   .0  .00
05               MEDIUM SILT LOAM
  .12  6.00      .30  79.00    6.9  13.9 1.0  1.32E-03   93.1  6.67    .04 1.00
  10.    .106    .262    .362    .262  1.000  1.37  1.16  2.5  3.3  6.5  .00
  15.    .106    .262    .362    .262   .819  1.37  1.10  2.4  3.2  6.5  .00
  15.    .107    .262    .362    .262   .607  1.37   .97  2.2  3.0  6.5  .00
  15.    .108    .261    .361    .261   .407  1.38   .75  2.0  2.7  6.5  .00
  15.    .108    .261    .361    .261   .407  1.38   .75  2.0  2.7  6.5  .00
  30.    .110    .260    .360    .260   .247  1.38   .49  1.8  2.3  6.5  .00
  30.    .111    .259    .359    .259   .135  1.39   .24  1.5  1.9  6.5  .00
  -1.    .00     .00     .00     .00    .00    .00   .00   .0   .0   .0  .00
```

Table 14 Continued. File "*SPROFILE.BN2.*"

```
06             SHALLOW SILT LOAM
  .12  6.00   .20  81.00   6.9  13.9 1.0  1.32E-03   93.3  6.67   .04 1.00
  10.   .106  .262   .362   .262  1.000  1.37  1.16  2.5  3.3  6.5  .00
  10.   .106  .262   .362   .262   .819  1.37  1.10  2.4  3.2  6.5  .00
  10.   .107  .262   .362   .262   .607  1.37   .97  2.2  3.0  6.5  .00
  10.   .108  .261   .361   .261   .449  1.38   .77  2.1  2.7  6.5  .00
  15.   .108  .261   .361   .261   .449  1.38   .77  2.1  2.7  6.5  .00
  -1.   .00   .00    .00    .00    .00    .00   .00   .0   .0   .0  .00
07             DEEP SANDY LOAM
  .13  6.00   .50  68.00   6.9  13.9 1.0  1.32E-03   98.3  6.67   .04 1.00
  10.   .086  .220   .320   .220  1.000  1.61   .70  2.5  3.3  6.5  .00
  15.   .086  .220   .320   .220   .819  1.61   .66  2.4  3.2  6.5  .00
  15.   .086  .220   .320   .220   .607  1.61   .58  2.2  3.0  6.5  .00
  15.   .086  .220   .320   .220   .607  1.61   .58  2.2  3.0  6.5  .00
  30.   .087  .219   .319   .219   .368  1.61   .43  2.0  2.6  6.5  .00
  30.   .088  .218   .318   .218   .202  1.62   .26  1.7  2.2  6.5  .00
  30.   .089  .218   .318   .218   .111  1.62   .12  1.4  1.8  6.5  .00
  30.   .089  .218   .318   .218   .061  1.62   .04  1.1  1.3  6.5  .00
  30.   .089  .217   .317   .217   .033  1.62   .01   .8   .9  6.5  .00
  -1.   .00   .00    .00    .00    .00    .00   .00   .0   .0   .0  .00
08             MEDIUM SANDY LOAM
  .13  6.00   .50  70.00   6.9  13.9 1.0  1.32E-03   98.3  6.67   .04 1.00
  10.   .086  .220   .320   .220  1.000  1.61   .70  2.5  3.3  6.5  .00
  15.   .086  .220   .320   .220   .819  1.61   .66  2.4  3.2  6.5  .00
  15.   .086  .220   .320   .220   .607  1.61   .58  2.2  3.0  6.5  .00
  15.   .087  .219   .319   .219   .407  1.61   .45  2.0  2.7  6.5  .00
  15.   .087  .219   .319   .219   .407  1.61   .45  2.0  2.7  6.5  .00
  30.   .088  .219   .319   .219   .247  1.62   .29  1.8  2.3  6.5  .00
  30.   .089  .218   .318   .218   .135  1.62   .15  1.5  1.9  6.5  .00
  -1.   .00   .00    .00    .00    .00    .00   .00   .0   .0   .0  .00
09             SHALLOW SANDY LOAM
  .13  6.00   .40  74.00   6.9  13.9 1.0  1.32E-03   98.4  6.67   .04 1.00
  10.   .086  .220   .320   .220  1.000  1.61   .70  2.5  3.3  6.5  .00
  10.   .086  .220   .320   .220   .819  1.61   .66  2.4  3.2  6.5  .00
  10.   .086  .220   .320   .220   .607  1.61   .58  2.2  3.0  6.5  .00
  10.   .087  .219   .319   .219   .449  1.61   .46  2.1  2.7  6.5  .00
  15.   .087  .219   .319   .219   .449  1.61   .46  2.1  2.7  6.5  .00
  -1.   .00   .00    .00    .00    .00    .00   .00   .0   .0   .0  .00
10             DEEP SAND
  .15  4.00   .60  65.00   6.9  13.9 1.0  1.32E-03  111.9  6.67   .04 1.00
  10.   .032  .107   .267   .107  1.000  1.66   .29  2.5  3.3  6.5  .00
  15.   .032  .107   .267   .107   .819  1.66   .28  2.4  3.2  6.5  .00
  15.   .032  .107   .267   .107   .607  1.66   .24  2.2  3.0  6.5  .00
  15.   .032  .107   .267   .107   .607  1.66   .24  2.2  3.0  6.5  .00
  30.   .032  .107   .267   .107   .368  1.66   .18  2.0  2.6  6.5  .00
  30.   .033  .106   .266   .106   .202  1.66   .11  1.7  2.2  6.5  .00
  30.   .033  .106   .266   .106   .111  1.66   .05  1.4  1.8  6.5  .00
  30.   .033  .106   .266   .106   .061  1.66   .01  1.1  1.3  6.5  .00
  30.   .033  .106   .266   .106   .033  1.66   .00   .8   .9  6.5  .00
  -1.   .00   .00    .00    .00    .00    .00   .00   .0   .0   .0  .00
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 11              MEDIUM SAND
  .15  4.00     .50  70.00     6.9  13.9 1.0  1.32E-03  112.0  6.67   .04 1.00
  10.   .032   .107   .267    .107  1.000  1.66    .29  2.5  3.3  6.5  .00
  15.   .032   .107   .267    .107   .819  1.66    .28  2.4  3.2  6.5  .00
  15.   .032   .107   .267    .107   .607  1.66    .24  2.2  3.0  6.5  .00
  15.   .032   .107   .267    .107   .407  1.66    .19  2.0  2.7  6.5  .00
  15.   .032   .107   .267    .107   .407  1.66    .19  2.0  2.7  6.5  .00
  30.   .033   .106   .266    .106   .247  1.66    .12  1.8  2.3  6.5  .00
  30.   .034   .105   .265    .105   .135  1.66    .06  1.5  1.9  6.5  .00
  -1.   .00    .00    .00     .00    .00    .00    .00   .0   .0   .0  .00
 12              SHALLOW SAND
  .15  4.00     .40  75.00     6.9  13.9 1.0  1.32E-03  112.0  6.67   .04 1.00
  10.   .032   .107   .267    .107  1.000  1.66    .29  2.5  3.3  6.5  .00
  10.   .032   .107   .267    .107   .819  1.66    .28  2.4  3.2  6.5  .00
  10.   .032   .107   .267    .107   .607  1.66    .24  2.2  3.0  6.5  .00
  10.   .032   .107   .267    .107   .449  1.66    .19  2.1  2.7  6.5  .00
  15.   .032   .107   .267    .107   .449  1.66    .19  2.1  2.7  6.5  .00
  -1.   .00    .00    .00     .00    .00    .00    .00   .0   .0   .0  .00
 13 Waipio, HI   Waipio (Clayey, kaolinitic, isohyperth, Tropeptic Eutrustox)
 0.14  5.00    0.60  60.00  22.0    7.0 1.0  1.32E-03   60.1  6.67  0.04 1.00
   5.  0.220  0.350  0.550  0.350  1.000  1.00  2.27    .0    .0  6.3  0.0
  10.  0.230  0.350  0.550  0.350  1.000  1.00  2.27    .0    .0  6.3  0.0
  15.  0.240  0.350  0.550  0.350  0.800  1.05  1.10    .0    .0  5.8  0.0
  20.  0.250  0.370  0.480  0.370  0.400  1.17  1.41    .0    .0  5.8  0.0
  20.  0.260  0.380  0.460  0.380  0.200  1.22  0.59    .0    .0  6.0  0.0
  20.  0.250  0.380  0.460  0.380  0.050  1.22  0.36    .0    .0  6.0  0.0
  20.  0.260  0.400  0.480  0.400  0.020  1.17  0.27    .0    .0  6.0  0.0
  -1.  0.000  0.000  0.000  0.000  0.000  0.00  0.00    .0    .0  0.0  0.0
 14 Gainesville  Millhopper Fine Sand (Loamy,silic,hyperth Arenic Paleudult)
 0.18 02.00  00.650  60.00  21.0  29.9 1.0  1.32E-03  114.2  6.67  0.04 0.84
   5.   .026   .096   .230    .096  1.000  1.30  2.00    .0    .0    .0   .00
  10.   .025   .086   .230    .086  0.500  1.30  1.00    .0    .0    .0   .00
  15.   .025   .086   .230    .086  0.250  1.40  1.00    .0    .0    .0   .00
  30.   .025   .086   .230    .086   .350  1.40  0.50    .0    .0    .0   .00
  30.   .028   .090   .230    .090   .100  1.45  0.10    .0    .0    .0   .00
  30.   .028   .090   .230    .090   .050  1.45  0.10    .0    .0    .0   .00
  30.   .029   .130   .230    .130   .000  1.45  0.04    .0    .0    .0   .00
  30.   .070   .258   .360    .258   .000  1.20  0.24    .0    .0    .0   .00
  -1.   .0     .0     .0      .0     .0     .0   0.0     .0    .0    .0   .00
 15 Millhopper   Millhopper Fine Sand (Loamy,silic,hyperth Gross. Paleudults)
000.18 05.00  00.50  66.00  21.0  29.9 1.0  1.32E-03  114.2  6.67  0.04 0.84
   5.   .023   .086   .230    .086  1.000   .00   .00    .0    .0    .0   7.4
  10.   .023   .086   .230    .086  0.500   .00   .00    .0    .0    .0   7.4
  15.   .023   .086   .230    .086  0.250   .00   .00    .0    .0    .0  15.8
  15.   .023   .086   .230    .086  0.250   .00   .00    .0    .0    .0  28.0
  15.   .023   .086   .230    .086  0.100   .00   .00    .0    .0    .0  28.0
  30.   .021   .076   .230    .076  0.100   .00   .00    .0    .0    .0  27.6
  30.   .020   .076   .230    .076  0.050   .00   .00    .0    .0    .0  17.5
  30.   .027   .130   .230    .130  0.000   .00   .00    .0    .0    .0   0.3
  30.   .070   .258   .360    .258  0.000   .00   .00    .0    .0    .0   .10
  -1.   .0     .0     .0      .0     .0     .0    .0     .0    .0    .0   .0
 16 Gainesville  Lake Fine Sand (Hyperthermic, coated Typic Quartzipsamments)
000.18 00.00  00.50  66.00  21.0  29.9 1.0  1.32E-03  114.4  6.67  0.04 0.84
   5.   .020   .089   .230    .089  1.000   .00   .00    .0    .0    .0   .00
  10.   .019   .068   .230    .068  0.500   .00   .00    .0    .0    .0   .00
  15.   .019   .068   .230    .068  0.250   .00   .00    .0    .0    .0   .00
  15.   .026   .075   .230    .075   .250   .00   .00    .0    .0    .0   .00
  15.   .026   .075   .230    .075   .100   .00   .00    .0    .0    .0   .00
  30.   .025   .073   .230    .073   .100   .00   .00    .0    .0    .0   .00
  30.   .022   .069   .230    .069   .050   .00   .00    .0    .0    .0   .00
  30.   .023   .072   .230    .072   .000   .00   .00    .0    .0    .0   .00
  30.   .035   .085   .230    .085   .000   .00   .00    .0    .0    .0   .00
  -1.   .0     .0     .0      .0     .0     .0    .0     .0    .0    .0   .0
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Table 14 Continued. File "*SPROFILE.BN2.*"

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17 Quincy, FL    Orangeburg Sandy Loam (F-loamy,silic,thermic Typ Paleudults)
 .13  9.00  00.27  84.00  21.0  29.9 1.0  1.32E-03   85.1  6.67  0.04 0.95
  5.   .125   .198   .294   .198  1.000  1.49  1.73   .0   .0   .0   .00
 10.   .125   .198   .294   .198   .874  1.49  1.73   .0   .0   .0   .00
 10.   .125   .198   .294   .198   .874  1.49  1.73   .0   .0   .0   .00
 09.   .117   .226   .323   .226   .351  1.41   .40   .0   .0   .0   .00
 09.   .117   .226   .323   .226   .351  1.41   .40   .0   .0   .0   .00
 10.   .138   .250   .332   .250   .310  1.44   .20   .0   .0   .0   .00
 11.   .138   .250   .332   .250   .310  1.44   .20   .0   .0   .0   .00
 38.   .167   .281   .331   .281   .302  1.57   .14   .0   .0   .0   .00
 43.   .182   .291   .334   .291   .077  1.59   .16   .0   .0   .0   .00
 30.   .162   .272   .320   .272   .036  1.61   .09   .0   .0   .0   .00
 28.   .154   .263   .319   .263   .006  1.58   .03   .0   .0   .0   .00
 -1.   .0     .0     .0     .0     .0     .0     .0    .0   .0   .0   .0
18 Manhattan,KS Haynie (Coarse-silty, mixed,calcareous,mesic Typ Udifluvent)
 0.14  5.00   0.60  60.00  12.0  32.0 1.0  1.32E-03   85.0  6.67  0.04 1.00
  15.  0.072  0.225  0.275  0.225  1.000  1.15  0.61   .0   .0   .0   .00
  15.  0.070  0.240  0.290  0.240  0.700  1.16  0.61   .0   .0   .0   .00
  30.  0.040  0.154  0.194  0.154  0.200  1.21  0.59   .0   .0   .0   .00
  30.  0.032  0.091  0.141  0.091  0.050  1.23  0.29   .0   .0   .0   .00
  30.  0.032  0.087  0.137  0.087  0.030  1.31  0.24   .0   .0   .0   .00
  30.  0.032  0.087  0.137  0.087  0.010  1.31  0.20   .0   .0   .0   .00
  30.  0.032  0.087  0.137  0.087  0.010  1.31  0.20   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0     .0    .0   .0   .0   .0
19 Swift, CAN    Wood Mountain Loam (Orthic Brown Chernozem)
 0.12  8.00   0.50  60.00   2.2  36.2 1.0  1.32E-03   94.7  6.67  0.04 1.00
   5.  0.096  0.230  0.250  0.230  1.000  0.00  1.10   .0   .0   .0   .00
  10.  0.096  0.230  0.250  0.230  0.800  0.00  1.10   .0   .0   .0   .00
  15.  0.112  0.250  0.260  0.250  0.700  0.00  0.61   .0   .0   .0   .00
  15.  0.094  0.220  0.230  0.220  0.500  0.00  0.61   .0   .0   .0   .00
  15.  0.103  0.220  0.230  0.220  0.250  0.00  0.59   .0   .0   .0   .00
  15.  0.103  0.220  0.230  0.220  0.150  0.00  0.15   .0   .0   .0   .00
  15.  0.102  0.250  0.220  0.250  0.080  0.00  0.10   .0   .0   .0   .00
  30.  0.102  0.250  0.220  0.250  0.050  0.00  0.10   .0   .0   .0   .00
  30.  0.102  0.250  0.220  0.250  0.050  0.00  0.10   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0     .0    .0   .0   .0   .0
20 Rothamsted    Rothamsted
 0.14  6.00   0.50  60.00  14.0  27.0 1.0  1.32E-03   73.8  6.67  0.04 1.00
  10.  0.110  0.280  0.330  0.280  1.000  1.10  1.16   .0   .0   .0   .00
  15.  0.150  0.320  0.420  0.320  0.900  1.20  1.00   .0   .0   .0   .00
  20.  0.220  0.370  0.420  0.370  0.700  1.25  0.68   .0   .0   .0   .00
  20.  0.220  0.370  0.420  0.370  0.500  1.25  0.26   .0   .0   .0   .00
  30.  0.220  0.370  0.420  0.370  0.200  1.25  0.25   .0   .0   .0   .00
  30.  0.220  0.370  0.420  0.370  0.100  1.25  0.20   .0   .0   .0   .00
  30.  0.220  0.370  0.420  0.370  0.050  1.25  0.20   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0     .0    .0   .0   .0   .0
21 Aleppo, SYR  Tel Hadya (Palexerollic Chromoxerert; high AWC)
 0.14  6.00   0.50  72.00  16.4  11.5 1.0  1.32E-03   63.5  6.67  0.04 1.00
  10.  0.210  0.340  0.357  0.340  1.000  1.30  0.50   .0   .0   .0   .00
  15.  0.210  0.350  0.367  0.350  0.700  1.30  0.50   .0   .0   .0   .00
  25.  0.230  0.360  0.380  0.360  0.500  1.30  0.50   .0   .0   .0   .00
  25.  0.260  0.380  0.400  0.380  0.150  1.30  0.40   .0   .0   .0   .00
  25.  0.270  0.390  0.410  0.390  0.040  1.30  0.35   .0   .0   .0   .00
  25.  0.300  0.380  0.400  0.380  0.020  1.30  0.30   .0   .0   .0   .00
  25.  0.300  0.375  0.390  0.375  0.010  1.30  0.30   .0   .0   .0   .00
  30.  0.300  0.375  0.390  0.375  0.020  1.30  0.30   .0   .0   .0   .00
  20.  0.300  0.375  0.390  0.375  0.001  1.30  0.30   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0     .0    .0   .0   .0   .0
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Table 14 Continued. File "*SPROFILE.BN2.*"

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 22 Aleppo, SYR  Tel Hadya (Palexerollic Chromoxerert; low AWC)
  0.14  6.00    0.50  72.00  16.4  11.5 1.0  1.32E-03   63.5  6.67  0.04 1.00
   10.  0.210  0.280  0.357  0.280  1.000  1.30  0.50   .0    .0    .0   .00
   15.  0.210  0.280  0.367  0.280  0.700  1.30  0.50   .0    .0    .0   .00
   25.  0.230  0.290  0.380  0.290  0.500  1.30  0.50   .0    .0    .0   .00
   25.  0.260  0.350  0.400  0.350  0.150  1.30  0.40   .0    .0    .0   .00
   25.  0.270  0.350  0.410  0.350  0.040  1.30  0.35   .0    .0    .0   .00
   25.  0.300  0.350  0.400  0.350  0.020  1.30  0.30   .0    .0    .0   .00
   25.  0.300  0.350  0.390  0.350  0.010  1.30  0.30   .0    .0    .0   .00
   30.  0.300  0.350  0.390  0.350  0.020  1.30  0.30   .0    .0    .0   .00
   20.  0.300  0.350  0.390  0.350  0.001  1.30  0.30   .0    .0    .0   .00
   -1.   .0     .0     .0     .0     .0     .0    .0    .0    .0    .0   .0
 23 Florence, SC Norfolk Loamy Sand
  0.14  5.00    0.60  60.00  16.8  20.0 1.0  1.32E-03   88.2  6.67  0.04 1.00
   10.  0.075  0.210  0.250  0.210  1.000  1.55  0.30   .0    .0    .0   .00
   10.  0.075  0.210  0.250  0.210  1.000  1.55  0.30   .0    .0    .0   .00
   21.  0.100  0.240  0.290  0.240  0.800  1.67  0.17   .0    .0    .0   .00
   30.  0.210  0.310  0.350  0.310  0.400  1.54  0.01   .0    .0    .0   .00
   30.  0.210  0.320  0.360  0.320  0.100  1.54  0.01   .0    .0    .0   .00
   25.  0.180  0.280  0.320  0.280  0.100  1.68  0.01   .0    .0    .0   .00
   25.  0.180  0.280  0.320  0.280  0.100  1.74  0.01   .0    .0    .0   .00
   -1.   .0     .0     .0     .0     .0     .0    .0    .0    .0    .0   .0
 24 Marianna, FL Norfolk Sandy Loam  (F-loamy,silic,thermic Typ Paleudults)
   .18  6.00     .10  77.00  20.0  30.0 1.0  1.32E-03   90.9  6.67  0.04 0.84
    5.   .061   .145   .312   .145  1.000  1.38  1.29   .0    .0  5.5   .00
    5.   .061   .145   .312   .145  1.000  1.38  1.29   .0    .0  5.5   .00
   10.   .050   .141   .302   .141   .775  1.42   .47   .0    .0  5.5   .00
   18.   .056   .165   .270   .165   .448  1.52   .28   .0    .0  5.5   .00
   20.   .198   .304   .359   .304   .300  1.48   .25   .0    .0  5.1   .00
   21.   .198   .304   .359   .304   .300  1.48   .25   .0    .0  5.1   .00
   16.   .197   .305   .335   .305   .100  1.64   .12   .0    .0  5.1   .00
   17.   .197   .305   .335   .305   .100  1.64   .12   .0    .0  5.1   .00
   17.   .184   .292   .332   .292   .100  1.61   .06   .0    .0  5.0   .00
   18.   .184   .292   .332   .292   .100  1.61   .06   .0    .0  5.0   .00
   26.   .210   .318   .339   .318   .020  1.67   .05   .0    .0  5.0   .00
   28.   .227   .335   .350   .335   .000  1.66   .06   .0    .0  4.9   .00
   28.   .227   .335   .350   .335   .000  1.66   .06   .0    .0  4.9   .00
   -1.   .000   .000   .000   .000   .000   .00   .00   .0    .0   .0   .00
 25 Raleigh, NC  Norfolk Sandy Clay Loam (F-l,silic.,therm. Typ. Paleudults)
000.14 03.00  00.23  60.0  16.8  20.0 1.0   1.32E-03  106.9  6.67  0.04 0.95
    5.0 0.042  0.169  0.392  0.169  1.000   .00   .00   .0    .0    .0   .00
   10.0 0.042  0.169  0.392  0.169  1.000   .00   .00   .0    .0    .0   .00
   10.0 0.042  0.169  0.392  0.169   .779   .00   .00   .0    .0    .0   .00
   08.0 0.044  0.177  0.358  0.177   .349   .00   .00   .0    .0    .0   .00
   13.0 0.056  0.165  0.396  0.165   .209   .00   .00   .0    .0    .0   .00
   15.0 0.150  0.291  0.377  0.291   .070   .00   .00   .0    .0    .0   .00
   15.0 0.150  0.291  0.377  0.291   .070   .00   .00   .0    .0    .0   .00
   30.0 0.150  0.291  0.377  0.291   .017   .00   .00   .0    .0    .0   .00
   30.0 0.150  0.291  0.377  0.291   .000   .00   .00   .0    .0    .0   .00
   -1.0  .0     .0     .0     .0     .0     .0    .0    .0    .0    .0   .0
 26 Castana, IO  Ida Silt Loam
000.12 06.00  00.30  60.00  12.0  32.0 1.0  1.32E-03   89.4  6.67  0.04 1.00
    5.   .135   .290   .485   .290  1.000   .00   .00   .0    .0    .0   .00
   10.   .135   .290   .485   .290  1.000   .00   .00   .0    .0    .0   .00
   15.   .135   .290   .485   .290   .175   .00   .00   .0    .0    .0   .00
   15.   .106   .228   .514   .228   .138   .00   .00   .0    .0    .0   .00
   15.   .106   .228   .514   .228   .138   .00   .00   .0    .0    .0   .00
   30.   .105   .254   .517   .254   .188   .00   .00   .0    .0    .0   .00
   30.   .133   .290   .507   .290   .250   .00   .00   .0    .0    .0   .00
   30.   .108   .283   .505   .283   .213   .00   .00   .0    .0    .0   .00
   30.   .108   .291   .542   .291   .100   .00   .00   .0    .0    .0   .00
   -1.   .0     .0     .0     .0     .0     .0    .0    .0    .0    .0   .0
```

Table 14 Continued. File "*SPROFILE.BN2.*"

```
27 Sumatra, IND Sitiung ( no subsoil acidity, Ultisol )
 0.14  5.00   0.60  60.00  22.0   7.0 1.0  1.32E-03   32.5  6.67  0.04 1.00
   5.   .328   .448   .550   .448  1.000  1.00  2.27   .0   .0   .0   .00
  10    .353   .472   .550   .472  1.000  1.00  2.27   .0   .0   .0   .00
  15.   .377   .497   .550   .497  0.750  1.05  1.10   .0   .0   .0   .00
  20.   .349   .482   .520   .482  0.350  1.17  1.41   .0   .0   .0   .00
  20.   .349   .492   .520   .492  0.150  1.22  0.59   .0   .0   .0   .00
  30.   .328   .476   .490   .476  0.100  1.22  0.36   .0   .0   .0   .00
  30.   .328   .448   .490   .448  0.001  1.17  0.27   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0    .0    .0   .0   .0   .0
28 Sumatra, IND Sitiung ( subsoil acidity, Ultisol )
 0.14  5.00   0.60  60.00  22.0   7.0 1.0  1.32E-03   33.3  6.67  0.04 1.00
   5.   .328   .448   .550   .448  1.000  1.00  2.27   .0   .0   .0   .00
  10    .353   .472   .550   .472  0.800  1.00  2.27   .0   .0   .0   .00
  15.   .377   .497   .550   .497  0.100  1.05  1.10   .0   .0   .0   .00
  20.   .349   .482   .520   .482  0.010  1.17  1.41   .0   .0   .0   .00
  20.   .349   .492   .520   .492  0.000  1.22  0.59   .0   .0   .0   .00
  30.   .328   .476   .490   .476  0.000  1.22  0.36   .0   .0   .0   .00
  30.   .328   .448   .490   .448  0.000  1.17  0.27   .0   .0   .0   .00
  -1.   .0     .0     .0     .0     .0     .0    .0    .0   .0   .0   .0
29 Hyderabad,IN Patancheru (Alfisol Udic Rhodustalf)
000.14 03.00  0.50  80.0  30.0    8.0 1.0  1.32E-03   97.1  6.67  0.04 1.00
   5.0 0.060  0.200  0.430  0.200  1.000   .00   .00   .0   .0   .0   .00
  12.0 0.060  0.200  0.430  0.200  1.000   .00   .00   .0   .0   .0   .00
  08.0 0.060  0.200  0.430  0.200  0.515   .00   .00   .0   .0   .0   .00
  15.0 0.076  0.192  0.430  0.192  0.458   .00   .00   .0   .0   .0   .00
  15.0 0.124  0.220  0.430  0.220  0.400   .00   .00   .0   .0   .0   .00
  15.0 0.160  0.220  0.430  0.220  0.286   .00   .00   .0   .0   .0   .00
  15.0 0.160  0.200  0.430  0.200  0.172   .00   .00   .0   .0   .0   .00
  15.0 0.160  0.200  0.430  0.200  0.057   .00   .00   .0   .0   .0   .00
  15.0 0.160  0.200  0.430  0.200  0.057   .00   .00   .0   .0   .0   .00
  -1.0 0.000  0.000  0.000  0.000  0.000   .0    .0    .0   .0   .0   .0
30 Palmira (M3W)Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
 0.09 11.02   0.40  84.00  24.0   0.0 1.0 1.32e-003   74.7  6.67  0.04 1.00
   5    0.204  0.340  0.392  0.340  1.000  1.45  2.19 -9.0 -9.0  6.9   0.0
  10    0.204  0.340  0.392  0.340  1.000  1.45  2.19 -9.0 -9.0  6.9   0.0
  10    0.209  0.345  0.390  0.345  0.750  1.45  1.21 -9.0 -9.0  7.2   0.0
  10    0.209  0.345  0.390  0.345  0.500  1.45  1.21 -9.0 -9.0  7.2   0.0
  15    0.198  0.335  0.390  0.335  0.350  1.49  0.53 -9.0 -9.0  8.0   0.0
  15    0.185  0.323  0.395  0.323  0.200  1.58  0.20 -9.0 -9.0  8.2   0.0
  15    0.185  0.323  0.395  0.323  0.150  1.58  0.20 -9.0 -9.0  8.2   0.0
  19    0.201  0.328  0.408  0.328  0.100  1.54  0.10 -9.0 -9.0  8.1   0.0
  23    0.198  0.325  0.410  0.325  0.050  1.58  0.09 -9.0 -9.0  8.2   0.0
  15    0.159  0.288  0.399  0.288  0.000  1.50  0.09 -9.0 -9.0  8.3   0.0
  22    0.110  0.242  0.402  0.242  0.000  1.69  0.10 -9.0 -9.0  8.3   0.0
  25    0.047  0.177  0.351  0.177  0.000  1.59  0.08 -9.0 -9.0  8.0   0.0
  25    0.050  0.193  0.410  0.193  0.000  1.45  0.12 -9.0 -9.0  8.5   0.0
  -1    0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
```

Table 14 Continued. File "*SPROFILE.BN2.*"

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31 Popayan     Loam (Fine-loamy,mixed,isothermic Typic (Andic) Dystrandept)
 0.09  8.72   0.60  84.00  18.0   0.0 1.0 1.32e-003  108.2  6.67  0.04 1.00
   5   0.075  0.215  0.406  0.215  1.000  0.58 16.80 -9.0 -9.0  5.7   0.0
   8   0.075  0.215  0.406  0.215  1.000  0.58 16.80 -9.0 -9.0  5.7   0.0
   8   0.039  0.175  0.371  0.175  0.750  0.55 15.80 -9.0 -9.0  4.9   0.0
   9   0.039  0.175  0.371  0.175  0.500  0.55 15.80 -9.0 -9.0  4.9   0.0
   9   0.050  0.164  0.302  0.164  0.500  0.52  6.87 -9.0 -9.0  5.1   0.0
  13   0.043  0.139  0.302  0.139  0.350  0.48  3.80 -9.0 -9.0  5.3   0.0
  14   0.043  0.139  0.302  0.139  0.200  0.48  3.80 -9.0 -9.0  5.3   0.0
  16   0.041  0.130  0.302  0.130  0.150  0.51  2.19 -9.0 -9.0  5.3   0.0
  20   0.044  0.140  0.302  0.140  0.100  0.62  1.88 -9.0 -9.0  5.3   0.0
  22   0.040  0.128  0.302  0.128  0.050  0.64  1.51 -9.0 -9.0  5.2   0.0
  13   0.045  0.145  0.302  0.145  0.000  0.51  1.66 -9.0 -9.0  5.2   0.0
  19   0.037  0.117  0.302  0.117  0.000  0.48  1.31 -9.0 -9.0  5.2   0.0
  20   0.037  0.117  0.302  0.117  0.000  0.48  1.31 -9.0 -9.0  5.2   0.0
  24   0.033  0.104  0.302  0.104  0.000  0.40  1.65 -9.0 -9.0  5.6   0.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
32 Palmira (N1N)Clay (Fine-silty,mixed,isohyperthermic Aquic Hapludoll)
 0.09 11.34   0.40  84.00  24.0   0.0 1.0 1.32e-003   71.8  6.67  0.04 0.85
   5   0.221  0.355  0.395  0.355  1.000  1.36  3.11 -9.0 -9.0  7.5   0.0
   7   0.221  0.355  0.395  0.355  1.000  1.36  3.11 -9.0 -9.0  7.5   0.0
   9   0.227  0.360  0.394  0.360  0.750  1.37  3.00 -9.0 -9.0  7.5   0.0
   9   0.227  0.360  0.394  0.360  0.750  1.37  3.00 -9.0 -9.0  7.5   0.0
  12   0.239  0.372  0.391  0.372  0.500  1.46  2.00 -9.0 -9.0  7.3   0.0
   8   0.205  0.339  0.398  0.339  0.500  1.56  1.26 -9.0 -9.0  8.0   0.0
   8   0.205  0.339  0.398  0.339  0.350  1.56  1.26 -9.0 -9.0  8.0   0.0
   8   0.137  0.274  0.410  0.274  0.250  1.52  0.45 -9.0 -9.0  8.2   0.0
   9   0.137  0.274  0.410  0.274  0.200  1.52  0.45 -9.0 -9.0  8.2   0.0
   7   0.053  0.200  0.397  0.200  0.150  1.44  0.16 -9.0 -9.0  8.1   0.0
  10   0.199  0.318  0.381  0.318  0.100  1.30  0.19 -9.0 -9.0  8.1   0.0
  10   0.198  0.319  0.406  0.319  0.100  1.32  0.15 -9.0 -9.0  8.1   0.0
  26   0.174  0.297  0.383  0.297  0.050  1.53  0.12 -9.0 -9.0  8.2   0.0
  24   0.182  0.308  0.379  0.308  0.000  1.59  0.18 -9.0 -9.0  8.2   0.0
  13   0.144  0.268  0.369  0.268  0.000  1.71  0.10 -9.0 -9.0  8.3   0.0
  28   0.091  0.208  0.335  0.208  0.000  1.67  0.07 -9.0 -9.0  8.3   0.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
33 Quilichao   Clay (Fine,Kaolinitic,Isohyperth. Oxic Dystropept)
 0.09  6.75   0.60  76.00  24.0   0.0 1.0 1.32e-003   20.0  6.67  0.04 1.00
   5   0.351  0.470  0.485  0.470  1.000  1.17  2.90 -9.0 -9.0  7.3   0.0
   3   0.351  0.470  0.485  0.470  1.000  1.17  2.90 -9.0 -9.0  7.3   0.0
   9   0.356  0.475  0.490  0.475  0.750  1.24  2.92 -9.0 -9.0  6.5   0.0
  13   0.374  0.491  0.506  0.491  0.750  1.19  2.45 -9.0 -9.0  4.7   0.0
   8   0.395  0.510  0.525  0.510  0.500  1.13  1.48 -9.0 -9.0  4.7   0.0
   8   0.395  0.510  0.525  0.510  0.350  1.13  1.48 -9.0 -9.0  4.7   0.0
  10   0.415  0.527  0.542  0.527  0.250  1.07  0.76 -9.0 -9.0  4.8   0.0
  11   0.415  0.527  0.542  0.527  0.200  1.07  0.76 -9.0 -9.0  4.8   0.0
  15   0.427  0.536  0.551  0.536  0.150  1.08  0.36 -9.0 -9.0  4.8   0.0
  16   0.427  0.536  0.551  0.536  0.100  1.08  0.36 -9.0 -9.0  4.8   0.0
  26   0.437  0.549  0.564  0.549  0.050  1.01  0.23 -9.0 -9.0  5.0   0.0
  28   0.441  0.553  0.568  0.553  0.000  1.00  0.15 -9.0 -9.0  5.3   0.0
  28   0.428  0.541  0.556  0.541  0.000  0.99  0.14 -9.0 -9.0  5.3   0.0
  18   0.371  0.488  0.503  0.488  0.000  1.10  0.08 -9.0 -9.0  5.4   0.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
```

Table 14 Continued. File "*SPROFILE.BN2.*"

```
34 Palmira (M2S)Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
 0.09 11.02   0.40  84.00  24.0   0.0 1.0 1.32e-003   74.7  6.67  0.04 0.85
   5   0.204  0.340  0.392  0.340  1.000  1.45  2.19 -9.0 -9.0  6.9   0.0
  10   0.204  0.340  0.392  0.340  1.000  1.45  2.19 -9.0 -9.0  6.9   0.0
  10   0.209  0.345  0.390  0.345  0.750  1.45  1.21 -9.0 -9.0  7.2   0.0
  10   0.209  0.345  0.390  0.345  0.500  1.45  1.21 -9.0 -9.0  7.2   0.0
  15   0.198  0.335  0.390  0.335  0.350  1.49  0.53 -9.0 -9.0  8.0   0.0
  15   0.185  0.323  0.395  0.323  0.200  1.58  0.20 -9.0 -9.0  8.2   0.0
  15   0.185  0.323  0.395  0.323  0.150  1.58  0.20 -9.0 -9.0  8.2   0.0
  19   0.201  0.328  0.408  0.328  0.100  1.54  0.10 -9.0 -9.0  8.1   0.0
  23   0.198  0.325  0.410  0.325  0.050  1.58  0.09 -9.0 -9.0  8.2   0.0
  15   0.159  0.288  0.399  0.288  0.000  1.50  0.09 -9.0 -9.0  8.3   0.0
  22   0.110  0.242  0.402  0.242  0.000  1.69  0.10 -9.0 -9.0  8.3   0.0
  25   0.047  0.177  0.351  0.177  0.000  1.59  0.08 -9.0 -9.0  8.0   0.0
  25   0.050  0.193  0.410  0.193  0.000  1.45  0.12 -9.0 -9.0  8.5   0.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
35 Culma    Culma Sandy Clay Loam (Jutiapa, Guatemala) Profile
 0.13 10.38   0.40  76.00  25.0   2.0 1.0  1.32e-03   66.1  6.67  0.04 0.75
   5   0.157  0.263  0.341  0.263  1.000  1.60  2.62 -9.0 -9.0  7.1  -9.0
  10   0.157  0.263  0.341  0.263  1.000  1.60  2.62 -9.0 -9.0  7.1  -9.0
   8   0.192  0.303  0.345  0.303  0.750  1.42  2.14 -9.0 -9.0  6.9  -9.0
   9   0.192  0.303  0.345  0.303  0.750  1.42  2.14 -9.0 -9.0  6.9  -9.0
  15   0.258  0.366  0.381  0.366  0.500  1.38  2.16 -9.0 -9.0  5.5  -9.0
  15   0.258  0.366  0.381  0.366  0.500  1.38  2.16 -9.0 -9.0  5.5  -9.0
  13   0.249  0.362  0.377  0.362  0.500  1.59  0.97 -9.0 -9.0  5.6  -9.0
  25   0.251  0.364  0.379  0.364  0.350  1.59  0.97 -9.0 -9.0  5.6  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
36 CATIE          Turrialba Clay (FINE ISOHYPERTH. HALLOYS. TYP. HUMITROPEPT)
 0.13 11.80   0.40  76.00  25.0   2.5 1.0  1.32e-03   56.2  6.67  0.04 1.00
   5   0.247  0.375  0.401  0.375  1.000  1.23  3.27 -9.0 -9.0  5.1  -9.0
  13   0.247  0.375  0.401  0.375  1.000  1.23  3.27 -9.0 -9.0  5.1  -9.0
  15   0.263  0.391  0.406  0.391  0.750  1.21  1.05 -9.0 -9.0  5.2  -9.0
  12   0.262  0.391  0.406  0.391  0.500  1.23  0.53 -9.0 -9.0  5.4  -9.0
  13   0.262  0.391  0.406  0.391  0.500  1.23  0.53 -9.0 -9.0  5.4  -9.0
  10   0.257  0.387  0.402  0.387  0.350  1.26  0.38 -9.0 -9.0  5.4  -9.0
  11   0.257  0.387  0.402  0.387  0.350  1.26  0.38 -9.0 -9.0  5.4  -9.0
  26   0.249  0.378  0.399  0.378  0.200  1.21  0.29 -9.0 -9.0  5.1  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
37 Quesada        FINE,MIXED,ISOHYPERTHERMIC VERTIC HAPLUSTOLL
 0.13  7.08   0.60  84.00  20.0   0.0 1.0 1.32e-003   57.6  6.67  0.04 1.00
   5   0.326  0.444  0.459  0.444  1.000  1.60  2.36 -9.0 -9.0  5.7  -9.0
  25   0.326  0.444  0.459  0.444  1.000  1.60  2.36 -9.0 -9.0  5.7  -9.0
  20   0.020  0.062  0.302  0.062  0.500  1.71  2.36 -9.0 -9.0  5.7  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
38 S Fernando     LOAMY-SKELETAL,MIXED,ISOHYPERTHERMIC TYPIC USTIFLUVENT
 0.13 11.25   0.40  80.00  20.0   0.0 1.0 1.32e-003   75.0  6.67  0.04 0.80
   5   0.191  0.299  0.369  0.299  1.000  1.27  2.25 -9.0 -9.0  7.0  -9.0
  10   0.191  0.299  0.369  0.299  1.000  1.27  2.25 -9.0 -9.0  7.0  -9.0
  30   0.160  0.273  0.352  0.273  0.750  1.11  0.87 -9.0 -9.0  6.7  -9.0
  27   0.244  0.361  0.376  0.361  0.500  1.30  1.20 -9.0 -9.0  6.7  -9.0
  23   0.170  0.285  0.355  0.285  0.350  1.13  0.67 -9.0 -9.0  6.9  -9.0
  25   0.095  0.207  0.332  0.207  0.200  1.02  0.36 -9.0 -9.0  7.0  -9.0
  30   0.163  0.266  0.363  0.266  0.150  1.28  0.60 -9.0 -9.0  7.1  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
```

Table 14 Continued. File "*SPROFILE.BN2.*"

```
39 Asuncion     CLAYEY-SKELETAL,MIXED,ISOHYPERTHERMIC USTIFLUVENT
 0.14 11.59   0.60  88.00  20.0   0.0 1.0 1.32e-003   71.2  6.67  0.04 1.00
   5   0.217  0.334  0.409  0.334  1.000  1.35  3.31 -9.0 -9.0  6.4  -9.0
  15   0.217  0.334  0.409  0.334  1.000  1.35  3.31 -9.0 -9.0  6.4  -9.0
  25   0.163  0.254  0.369  0.254  0.750  0.98  1.10 -9.0 -9.0  6.5  -9.0
  17   0.251  0.372  0.407  0.372  0.500  1.36  0.81 -9.0 -9.0  6.4  -9.0
  17   0.251  0.372  0.407  0.372  0.500  1.36  0.81 -9.0 -9.0  6.4  -9.0
  22   0.135  0.234  0.373  0.234  0.200  0.93  0.58 -9.0 -9.0  6.7  -9.0
  22   0.135  0.234  0.373  0.234  0.200  0.93  0.58 -9.0 -9.0  6.7  -9.0
  22   0.135  0.234  0.373  0.234  0.200  0.93  0.58 -9.0 -9.0  6.7  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
40 Goiania, Bz. CLAYEY, OXIDIC, HYPERTHERMIC TYPIC HAPLORTHOX
 0.14  7.56   0.80  88.00  20.0   0.0 1.0 1.32e-003   48.8  6.67  0.04 1.00
   5   0.291  0.412  0.427  0.412  1.000  1.15  1.50  0.3 -9.0  5.0  -9.0
  13   0.291  0.412  0.427  0.412  1.000  1.15  1.50  0.3 -9.0  5.0  -9.0
  20   0.329  0.446  0.461  0.446  0.500  1.15  1.31 -9.0 -9.0  4.9  -9.0
  18   0.332  0.450  0.465  0.450  0.500  1.17  0.93 -9.0 -9.0  5.1  -9.0
  29   0.326  0.444  0.459  0.444  0.350  1.39  0.85 -9.0 -9.0  5.3  -9.0
  23   0.253  0.375  0.390  0.375  0.100  1.07  0.68 -9.0 -9.0  5.7  -9.0
  23   0.253  0.375  0.390  0.375  0.100  1.07  0.68 -9.0 -9.0  5.7  -9.0
  23   0.253  0.375  0.390  0.375  0.000  1.07  0.68 -9.0 -9.0  5.7  -9.0
  26   0.253  0.375  0.390  0.375  0.000  1.07  0.68 -9.0 -9.0  5.7  -9.0
  25   0.240  0.361  0.376  0.361  0.000  1.13  0.47 -9.0 -9.0  5.7  -9.0
  25   0.240  0.361  0.376  0.361  0.000  1.13  0.47 -9.0 -9.0  5.7  -9.0
  25   0.240  0.361  0.376  0.361  0.000  1.13  0.47 -9.0 -9.0  5.7  -9.0
  25   0.240  0.361  0.376  0.361  0.000  1.13  0.47 -9.0 -9.0  5.7  -9.0
  25   0.237  0.358  0.373  0.358  0.000  1.50  0.32 -9.0 -9.0  6.0  -9.0
  25   0.237  0.358  0.373  0.358  0.000  1.50  0.32 -9.0 -9.0  6.0  -9.0
  25   0.237  0.358  0.373  0.358  0.000  1.50  0.32 -9.0 -9.0  6.0  -9.0
  25   0.237  0.358  0.373  0.358  0.000  1.50  0.32 -9.0 -9.0  2.2  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
41 S82PR007002  CLAYEY,KAOLINITIC,ISOHYPERTHERMIC TROPEPTIC EUTRUSTOX
 0.14  7.23   0.50  84.00  20.0   0.0 1.0  1.32e-03   37.5  6.67  0.04 1.00
   5   0.209  0.321  0.441  0.426  0.500  1.37  1.62 -9.0 -9.0  5.7  -9.0
   8   0.209  0.321  0.441  0.426  0.500  1.37  1.62 -9.0 -9.0  5.7  -9.0
  12   0.226  0.348  0.439  0.424  0.500  1.33  1.60 -9.0 -9.0  5.7  -9.0
  10   0.251  0.373  0.448  0.433  0.200  1.26  0.48 -9.0 -9.0  5.6  -9.0
  10   0.251  0.373  0.448  0.433  0.200  1.26  0.48 -9.0 -9.0  5.6  -9.0
  10   0.242  0.316  0.482  0.467  0.200  1.45  0.38 -9.0 -9.0  5.6  -9.0
  10   0.242  0.316  0.482  0.467  0.200  1.45  0.38 -9.0 -9.0  5.6  -9.0
  12   0.237  0.336  0.488  0.473  0.200  1.48  0.34 -9.0 -9.0  5.5  -9.0
  13   0.237  0.336  0.488  0.473  0.200  1.48  0.34 -9.0 -9.0  5.5  -9.0
  17   0.221  0.314  0.462  0.447  0.116  1.50  0.23 -9.0 -9.0  5.6  -9.0
  18   0.221  0.314  0.462  0.447  0.116  1.50  0.23 -9.0 -9.0  5.6  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
42 Colwood, MSU FINE-LOAMY, MIXED, MESIC TYPIC HAPLAQUOLL
 0.09 20.49   0.05  84.00  20.0   0.0 1.0  1.32e-03   89.9  6.67  0.04 0.85
   5   0.076  0.194  0.317  0.194  1.000  1.52  2.42 -9.0 -9.0  6.5  -9.0
  11   0.076  0.194  0.317  0.194  1.000  1.52  2.42 -9.0 -9.0  6.5  -9.0
  12   0.076  0.194  0.317  0.194  1.000  1.52  2.42 -9.0 -9.0  6.5  -9.0
  12   0.089  0.208  0.325  0.208  0.750  1.70  0.36 -9.0 -9.0  7.4  -9.0
  13   0.089  0.208  0.325  0.208  0.750  1.70  0.36 -9.0 -9.0  7.4  -9.0
  13   0.165  0.296  0.391  0.296  0.500  1.45  0.31 -9.0 -9.0  7.7  -9.0
  20   0.164  0.296  0.395  0.296  0.500  1.55  0.23 -9.0 -9.0  8.0  -9.0
  13   0.118  0.243  0.359  0.243  0.350  1.58  0.10 -9.0 -9.0  8.1  -9.0
  26   0.168  0.304  0.403  0.304  0.200  1.50  0.12 -9.0 -9.0  8.2  -9.0
  27   0.168  0.304  0.403  0.304  0.100  1.50  0.12 -9.0 -9.0  8.2  -9.0
  -1   0.000  0.000  0.000  0.000  0.000  0.00  0.00  0.0  0.0  0.0   0.0
```

FILE4 - Crop Residues

Table 15. File *"IGQU8903.BN4."*

IGQU8903	1	600	15	75	60
IGQU8903	2	600	15	75	60
IGQU8903	3	600	15	75	60

Table 16. File "*CCPA8629.BN5* (Only the first two treatments are shown)."

```
01 CCPA8629
   5. 0.340 12.0  15.0   6.9
  10. 0.340 12.0  15.0   6.9
  10. 0.345 12.0  15.0   7.2
  10. 0.345 12.0  15.0   7.2
  15. 0.335 12.0  15.0   8.0
  15. 0.323 11.0   4.0   8.2
  15. 0.323 11.0   4.0   8.2
  19. 0.328  7.0   4.0   8.1
  23. 0.325  7.0   4.0   8.2
  15. 0.288  7.0   4.0   8.3
  22. 0.242  7.0   4.0   8.3
  25. 0.177  7.0   4.0   8.0
  25. 0.193  7.0   4.0   8.5
  -1.  -1.   -1.   -1.   -1.
02 CCPA8629
   5. 0.340 12.0  15.0   6.9
  10. 0.340 12.0  15.0   6.9
  10. 0.345 12.0  15.0   7.2
  10. 0.345 12.0  15.0   7.2
  15. 0.335 12.0  15.0   8.0
  15. 0.323 11.0   4.0   8.2
  15. 0.323 11.0   4.0   8.2
  19. 0.328  7.0   4.0   8.1
  23. 0.325  7.0   4.0   8.2
  15. 0.288  7.0   4.0   8.3
  22. 0.242  7.0   4.0   8.3
  25. 0.177  7.0   4.0   8.0
  25. 0.193  7.0   4.0   8.5
  -1.  -1.   -1.   -1.   -1.
```

FILE6 - Irrigation Managements

Table 17. File "CCPA8629.BN6 (only the first five treatments are shown)."

```
01 CCPA8629
 269  30.00
 324  25.00
  -1  -1.00
02 CCPA8629
 269  30.00
 324  25.00
  -1  -1.00
03 CCPA8629
 269  30.00
 324  25.00
  -1  -1.00
04 CCPA8629
 269  30.00
 324  25.00
  -1  -1.00
05 CCPA8629
 269  30.00
 324  25.00
  -1  -1.00
```

Table 18. File *"CCPA8629.BN7"*.

```
01 CCPA8629
 269  15.0   4.0  99
  -1  -1.00 -1.0  -1
02 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
03 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
04 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
05 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
06 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
07 CCPA8629
 269  15.0   4.0  99
  -1  -1.0  -1.0 -1
08 CCPA8629
 269  07.5   4.0  99
  -1  -1.0  -1.0 -1
09 CCPA8629
 269  07.5   4.0  99
  -1  -1.0  -1.0 -1
10 CCPA8629
 269  07.5   4.0  99
  -1  -1.0  -1.0 -1
11 CCPA8629
 269  07.5   4.0  99
  -1  -1.0  -1.0 -1
12 CCPA8629
 269  07.5   4.0  99
  -1  -1.0  -1.0 -1
```

Table 19. File "CCPA8629.BN8."

```
CCPA8629 01 Porrillo Sin.  0.3 m row by 15 pl/m2        30   01
 239 269  15.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 02 Porrillo Sin.  0.3 m row by 30 pl/m2        30   01
 239 269  30.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 03 Porrillo Sin.  0.6 m row by 15 pl/m2        30   01
 239 269  15.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 04 Porrillo Sin.  0.6 m row by 30 pl/m2        30   01
 239 269  30.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 05 BAT 477        0.3 m row by 15 pl/m2        30   02
 239 269  15.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 06 BAT 477        0.3 m row by 30 pl/m2        30   02
 239 269  30.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 07 BAT 477        0.6 m row by 15 pl/m2        30   02
 239 269  15.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 08 BAT 477        0.6 m row by 30 pl/m2        30   02
 239 269  30.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 09 BAT 881        0.3 m row by 15 pl/m2        30   05
 239 269  15.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 10 BAT 881        0.3 m row by 30 pl/m2        30   05
 239 269  30.00  0.300  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 11 BAT 881        0.6 m row by 15 pl/m2        30   05
 239 269  15.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
CCPA8629 12 BAT 881        0.6 m row by 30 pl/m2        30   05
 239 269  30.00  0.600  2.00  2 00   1.00 00.30   50.0  00.00  0
```

Appendix C
CULTIVAR AND CROP COEFFICIENT FILES

FILE9 - Cultivar-Specific Coefficients

Table 20 File *"GENETICS.BN9."*

```
 01 Porrillo Sintetico    03 01                   VARIETY 1,PHOT. P 3,TEMP 1
 12.17 18.00  0.20                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 27.0 04.0 11.00 12.0 17.00 PHTHRS(J),J=1,9
 26.00 09.00 12.0 22.0                            PHTHRS(J),J=10,13
 45.00  20.0   5.2                                SHVAR,SDVAR,SDPDVR
  33.0  66.0  0.230                               PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  78.0                              XFRT,DETVEG,CNMOB,THRESH
 02 BAT 477               01 01                   VARIETY 2,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 26.0 03.0 10.00 11.0 15.00 PHTHRS(J),J=1,9
 26.00 10.00 10.0 22.0                            PHTHRS(J),J=10,13
 45.00  20.0   5.2                                SHVAR,SDVAR,SDPDVR
  30.0  60.0  0.230                               PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  78.0                              XFRT,DETVEG,CNMOB,THRESH
 03 Seafarer              01 01                   VARIETY 3,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 21.0 03.0 11.00 12.0 22.00 PHTHRS(J),J=1,9
 32.00 09.00 07.0 15.0                            PHTHRS(J),J=10,13
 35.00  17.0   5.0                                SHVAR,SDVAR,SDPDVR
  18.0  36.0  0.230                               PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.00                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  78.0                              XFRT,DETVEG,CNMOB,THRESH
 04 C-20                  01 01                   VARIETY 4,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 28.0 03.0 11.00 12.0 25.00 PHTHRS(J),J=1,9
 35.00 09.00 07.0 20.0                            PHTHRS(J),J=10,13
 39.00  17.0   5.0                                SHVAR,SDVAR,SDPDVR
  15.0  30.0  0.230                               PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.00                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  78.0                              XFRT,DETVEG,CNMOB,THRESH
 05 BAT 881               01 01                   VARIETY 5,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 28.0 03.0 11.00 12.0 15.00 PHTHRS(J),J=1,9
 26.00 09.00 10.0 22.0                            PHTHRS(J),J=10,13
 27.00  16.0   5.0                                SHVAR,SDVAR,SDPDVR
  31.0  62.0 0.230                                PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  82.0                              XFRT,DETVEG,CNMOB,THRESH
 06 ICTA-Ostua            01 01                   VARIETY 6, PHOT. GRP 1
 12.17 18.00  0.00                                CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 25.0 03.0 10.00 12.0 19.00 PHTHRS(J),J=1,9
 30.00 09.00 00.0 22.0                            PHTHRS(J),J=10,13
 28.00 015.0   5.4                                SHVAR,SDVAR,SDPDVR
 30.0   60.0   0.230                              PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                          TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  78.0                              XFRT,DETVEG,CNMOB,THRESH
```

Table 20 Continued. File *"GENETICS.BN9."*

```
 07 Rabia de Gato          03 01                         VARIETY 7, PHOT. GRP 3
 12.17 18.00  0.30                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 20.0 04.0 10.00 12.0 25.00 PHTHRS(J),J=1,9
 30.00 08.00 00.0 05.0                                   PHTHRS(J),J=10,13
 50.00 020.0   5.4                                       SHVAR,SDVAR,SDPDVR
  35.0  70.0   0.230                                     PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  78.0                                     XFRT,DETVEG,CNMOB,THRESH
 08 Turbo III              03 01                         VARIETY 8, PHOT. GRP 3
 12.17 18.00  0.35                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 28.0 03.0 09.00 12.0 19.00 PHTHRS(J),J=1,9
 30.00 09.00 00.0 05.0                                   PHTHRS(J),J=10,13
 21.00 018.0   5.4                                       SHVAR,SDVAR,SDPDVR
  20.0  40.0  0.230                                      PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  78.0                                     XFRT,DETVEG,CNMOB,THRESH
 09 Cuarentena             01 01                         VARIETY 9,PHOT. P1, TEMP 1
 12.17 18.00  0.00                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 23.0 03.0 12.00 13.0 17.00 PHTHRS(J),J=1,9
 27.00 09.00 09.0 22.0                                   PHTHRS(J),J=10,13
 40.00  30.0   3.2                                       SHVAR,SDVAR,SDPDVR
  40.0  80 0.230                                         PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  78.0                                     XFRT,DETVEG,CNMOB,THRESH
 10 Carioca                01 01                         VARIETY 10,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 25.0 04.0 11.00 12.0 17.00 PHTHRS(J),J=1,9
 31.00 09.00 12.0 22.0                                   PHTHRS(J),J=10,13
 30.00  15.0   4.0                                       SHVAR,SDVAR,SDPDVR
  23.0  46.0  0.230                                      PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.20                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.040  78.0                                     XFRT,DETVEG,CNMOB,THRESH
 11 Isabella               01 01                         VARIETY 11,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 21.0 02.5 08.00 09.0 15.00 PHTHRS(J),J=1,9
 32.00 09.00 00.0 22.0                                   PHTHRS(J),J=10,13
 48.00  19.0   2.5                                       SHVAR,SDVAR,SDPDVR
  24.0  60.0  0.235                                      PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.00                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  72.0                                     XFRT,DETVEG,CNMOB,THRESH
 12 Manitou                01 01                         VARIETY 12,PHOT. P 1,TEMP 1
 12.17 18.00  0.00                                       CSDVAR,CLDVAR,THVAR
3.50  05.00 0.0 5.00 24.0 07.0 13.00 14.0 18.00 PHTHRS(J),J=1,9
 38.00 09.00 00.0 15.0                                   PHTHRS(J),J=10,13
 50.00  20.0   2.5                                       SHVAR,SDVAR,SDPDVR
  25.0  50.0  0.235                                      PODVAR,FLWMAX,SDPRO
0.400 133.0 295.00  1.00                                 TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  72.0                                     XFRT,DETVEG,CNMOB,THRESH
```

Table 20 Continued. File "*GENETICS.BN9.*"

```
 13 ICA Linea 24         08 01                VARIETY 13,PHOT. P 8,TEMP 2
 12.17 18.00  0.45                            CSDVAR,CLDVAR,THVAR
3.50  04.00 0.0 5.00 28.0 03.0 06.00 08.0 12.00 PHTHRS(J),J=1,9
 29.00 09.00  0.0 25.0                        PHTHRS(J),J=10,13
 56.00  19.0   3.2                            SHVAR,SDVAR,SDPDVR
  20.0  40.0  0.235                           PODVAR,FLWMAX,SDPRO
0.400 133.0 310.00  1.00                      TRIFOL,SIZELF,SLAVAR,LFMAX
1.00 1.0 0.050  72.0                          XFRT,DETVEG,CNMOB,THRESH
```

Table 21 File "*CROPPARM.BN0.*"

```
330                             CO2BAS
48.27 40.30 1.67 -0.0173        PARMAX,PHTMAX,PHFAC1,PHFAC2
-1.599 5.449 -2.8498 6 6        CNIT1,CNIT2,CNIT3,NPHOTO,NLMAXT
0.0 0.0 5.0 0.0 21.0 1.0 31.0 1.0 45.0 0.0 50.0 0.0 XPHOTO,YPHOTO
0.0 0.0 8.0 0.0 30.0 1.0 35.0 1.0 48.0 0.0 60.0 0.0 XLMAXT,YLMAXT
1.50 1.77 30                    PHPT1,PHPT2,NLITE
0.0 0.0 0.1 0.1243 0.2 0.1917 0.3 0.2564 0.4 0.3183 0.5 0.3773
0.6 0.4336 0.7 0.4870 0.8 0.5376 0.9 0.5855 1.0 0.6305 1.1 0.6728
1.2 0.7122 1.3 0.7488 1.4 0.7826 1.5 0.8137 1.6 0.8419 1.8 0.8899
2.0 0.9267 2.2 0.9523 2.4 0.9667 2.6 0.9717 2.8 0.9785 3.0 0.9837
3.5 0.9918 4.0 0.9959 4.5 0.9979 5.0 0.9989 7.5 1.0000 8.0 1.0000
0.0541  0.20  0.8                 EFF SCV KDIF
0.43000  0.35000  0.22000         LFANGD
3.5E-04  0.0040                   RES30C,R30C2
1.50   1.32   1.28   1.16 1.52    AGRLF,AGRSTM,AGRRT,AGRSD2,AGRSH
.235 .640 .030 .020 .040 .035     SDPROS,PCARSD,PLIPSD,PLIGSD,POASD,PMINSD
2.478 2.478                       RNO3C,RNH4C
1.242 3.106 2.174 .929 .05  1.13  RCH2O,RLIP,RLIG,ROA,RMIN
0.68                              ALPHBR
0.210 0.070 0.120 0.050           PROLFI,PROLFF,PROSTI,PROSTF
0.100 0.100 0.200 0.080           PRORTI,PRORTF,PROSHI,PROSHF
3.00 0.25 0.15                    SENRTE,SENRT2,SENDAY
0.0 0.0 5.0 0.0 08.0 0.25 30.0 0.50        XSTAGE,SENPOR
3.0 0.1 5.0 0.3 10.0 0.80 30.0 0.80          XSENMX,SENMAX
0.60 0.30                         FRSTMF,FRLFF
1.00  0.00                        ATOP,STRCON
7                                 NVSPT
0.0 .35 1.8 .55 4.0 .60 6.5 0.55 8.5 0.45 9.5 .40 12.0 0.30 30. .30  XLEAF,YLEAF
0.0 .15 1.8 .25 4.0 .30 6.5 0.35 8.5 0.45 9.5 .50 12.0 0.60 30. .60  XSTEM,YSTEM
240. 300. 133.0                   FINREF,SLAREF,SIZREF
0.3 0900. 250.0  -0.0350  0.50    CONGR1,SLAMAX,SLAMIN,SLAPAR,THICKN
1.0                               VSSINK
0.0 0. 0.04 33. 1.83  93. 2.8 197. 4.3 500. 6.8 1000. 9.6 1500.  XVGROW,YVREF
25.0 09000 0.025 0.1 0.05         RTDEPI,RFAC1,RTSEN,RLDSM,RTSDF
0.0 2.50 3.0 2.50 6.0 1.50 30.0 1.00   XRTFAC,YRTFAC
0.90  1.0  0.100  10  0.0         SETMAX,SRMAX,RFLWAB,LNGSH,SHTHIC
5.00  20.00  1.00                 CONSD1,CONSD2,CONSD3
0.150 0.30                        WTNEW,PORPT
-2.22 -5.00                       FREEZ1,FREEZ2
01.50                             RWUEP1
```

Table 21 Continued. File *"CROPPARM.BN0."*

```
 2  6                                  NDVTEM,NDEVRT
0.0  0.0   1.0   1.0   0.0   0.0  DEVRT
-50. 5.0  30.0  45.0  80.0  90.0  VEGDV1
-50. 5.0  20.0  30.0  60.0  90.0  REPDVA1
-50. 5.0  15.0  60.0  80.0  90.0  REPDVB1
-50. 5.0  18.0  23.0  60.0  90.0  VEGDV2
-50. 5.0  18.0  23.0  60.0  90.0  REPDVA2
-50. 5.0  18.0  23.0  60.0  90.0  REPDVB2
1 1 1 2 3 3 4 4 4 4 4 8 3 3       NTYACC(JJ),JJ=1,14
1 1 2 2 4 5 6 6 6 6 6 11 6 6      NPRIOR(JJ),JJ=1,14
10                                                          NXYTEM
-50. 00.00  7.00 14.00 27.00 32.22 37.78 40.56 40.91  80.0   XTEMPD
 00. 00.00 00.00 01.00 01.00 0.828 0.505 0.061 0.000  00.0   YTEMPD
6                                                           NXFTEM
00.00 10.00 20.00 26.00 32.00 60.00                         XXFTEM
00.00 00.00 01.00 01.00 01.00 01.00                         YXFTEM
00.00  -1.00  1.0                                           XFRMAX,TURSEN,TURTHR
4                                                           NSWFAC
00.00  0.50  1.00  1.00                                     XSWFAC
 0.00  1.00 01.00 01.00                                     YSWFAC
5 1.50                                                      NSLATM, TURSLA
-50.00 00.00 14.00 24.00 60.00                              XSLATM
 00.50 00.50 00.50 01.00 01.00                              YSLATM
12                                                          NPGSLW
0.0      0.001  0.0015  0.002  0.0025  0.003
0.0035  0.004  0.005   0.006  0.008   0.010                 XPGSLW
0.162  0.679  0.790  0.867  0.923  0.966
1.000  1.027  1.069  1.100  1.141  1.167                    YPGSLW
14                                                          NVSHT
-1.00   0.00   1.96   2.67   4.25   6.75  8.00
9.58    10.00  12.00  14.00  16.00  20.00  40.0             XVSHT
0.00    0.0442 0.0084 0.0260 0.0437 0.1000 0.1000
0.1139 0.1300 0.1300 0.1300 0.1300 0.1000 0.0250            YVSHT
5                                                           NHWTEM
-50.00 00.00 15.00 20.00 60.00                              XHWTEM
 00.55 00.55 00.55 01.00 01.00                              YHWTEM
6                                                           NHWTUR
-1.00 00.00 00.50  0.75  1.00  1.00                         XHWTUR
00.10 00.10 00.50 00.75 01.00 01.00                         YHWTUR
9                                                           NHWPAR
-1.0 00.00 05.00  7.50 10.00 15.00 20.00 30.00 80.00 XHWPAR
04.0 04.00 02.00 01.50 01.25 01.05 01.00 01.00 01.00 YHWPAR
8                                                           NHWDL
-1.0 00.00 04.00 08.00 12.00 16.00 20.00 24.00              XHWDL
01.0 01.00 01.00 01.00 01.00 01.00 01.00 01.00              YHWDL
14                                                          NVSWH
-1.00   0.00   1.00   2.00   3.00   4.00   6.00
8.00    10.08  12.00  14.00  16.00  20.00  40.0             XVSWH
0.00    0.0250 0.0250 0.0250 0.0500 0.0750 0.0750
0.0750 0.0500 0.0250 0.0000 0.0000 0.0000 0.0000            YVSWH
```

Appendix D
FIELD MEASURED DATA FILES

FILEA - Measured Phenology and Growth Summary Data

Table 22 File "*CCPA8629.BNA.*"

```
CCPA8629 01   3328.  0.1882  1768. 5.89  6.61  6231. 1502.  307 341
 000 000   4225.  00.00
CCPA8629 02   4204.  0.1917  2193. 5.59  7.18  7809. 1957.  306 340
 000 000   5400.  00.00
CCPA8629 03   2786.  0.1987  1402. 5.10  6.15  5487. 1474.  306 340
 000 000   3559.  00.00
CCPA8629 04   3692.  0.1770  2086. 6.24  6.72  7326. 1881.  305 342
 000 000   4747.  00.00
CCPA8629 05   2667.  0.2015  1324. 5.29  7.99  5537. 1327.  304 342
 000 000   3373.  00.00
CCPA8629 06   3676.  0.1867  1969. 5.54  6.72  7299. 1783.  304 343
 000 000   4591.  00.00
CCPA8629 07   3548.  0.1930  1838. 5.27  6.64  7113. 1588.  305 342
 000 000   4570.  00.00
CCPA8629 08   3896.  0.2097  1858. 4.75  6.70  7701. 1747.  304 344
 000 000   4979.  00.00
CCPA8629 09   3083.  0.1900  1623. 4.40  5.64  6181. 1661.  308 343
 000 000   3797.  00.00
CCPA8629 10   3323.  0.1760  1888. 5.05  7.44  6568. 1843.  308 344
 000 000   4097.  00.00
CCPA8629 11   3467.  0.2037  1702. 4.50  5.47  6407. 1562.  308 342
 000 000   4194.  00.00
CCPA8629 12   3260.  0.1812  1799. 4.72  6.17  6306. 1643.  307 343
 000 000   4013.  00.00
```

Table 23 File "*CCPA8629.BNB.*" (Only the first two treatments are shown).

```
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  1
11 1 2 3 4 5 6 7 8 9 13 14
289    5.1 1.12    0.0  104.00    0.00  250.00  354.00    0.00    0.00      .   446.84
289    5.1 0.83    0.0   98.00    0.00  242.00  340.00    0.00    0.00      .   342.36
289    5.0 0.58    0.0   64.00    0.00  152.00  216.00    0.00    0.00      .   379.23
289    4.8 0.69    0.0   78.00    0.00  204.00  282.00    0.00    0.00      .   337.23
296      . 2.21    0.0  402.00    0.00  790.00 1192.00    0.00    0.00      .   279.29
296      . 1.62    0.0  304.00    0.00  556.00  860.00    0.00    0.00      .   291.98
296      . 1.43    0.0  202.00    0.00  444.00  646.00    0.00    0.00      .   320.99
296      . 1.35    0.0  154.00    0.00  438.00  592.00    0.00    0.00      .   308.17
305      . 5.38    0.0 1086.00    0.00 1214.00 2300.00    0.00    0.00      .   442.91
305      . 4.46    0.0 1004.00    0.00 1128.00 2132.00    0.00    0.00      .   395.24
305      . 4.52    0.0  826.00    0.00 1062.00 1888.00    0.00    0.00      .   425.33
305      . 4.91    0.0  988.00    0.00 1182.00 2170.00    0.00    0.00      .   415.49
311      . 5.67   68.0 1312.00    0.00 1296.00 2612.00    4.00    4.00   0.00  437.80
311      . 4.55  122.0 1580.00    0.00 1728.00 3318.00   10.00   10.00   0.00  263.25
311      . 1.42   36.0 1016.00    0.00 1008.00 2026.00    2.00    2.00   0.00  140.42
311      . 3.93   60.0 1286.00    0.00 1566.00 2856.00    4.00    4.00   0.00  250.87
316      . 7.25  488.0 1888.00    0.00 1658.00 3792.00  246.00  246.00   0.00  437.29
316      . 6.35  492.0 1962.00    0.00 1678.00 3894.00  254.00  254.00   0.00  378.69
316      . 7.73  406.0 1664.00    0.00 1364.00 3212.00  184.00  184.00   0.00  566.44
316      . 5.10  290.0 1472.00    0.00 1218.00 2832.00  142.00  142.00   0.00  419.04
328      . 8.39  542.0 2712.00 1344.00 2432.00 8354.00 3210.00 1866.00  41.87  345.05
328      . 4.59  548.0 1946.00 1408.00 1480.00 6224.00 2798.00 1390.00  50.32  309.83
328      . 7.15  390.0 2320.00  998.00 1724.00 6574.00 2530.00 1532.00  39.45  414.84
328      . 2.72  234.0 1296.00  490.00  606.00 2888.00  986.00  496.00  49.70  449.40
335      . 1.89  272.0 1306.00 1870.00  610.00 4652.00 2736.00  866.00  68.35  309.17
335      . 2.89  386.0 1538.00 2308.00 1068.00 6108.00 3502.00 1194.00  65.91  270.41
335      . 7.08  400.0 2520.00 3062.00 1726.00 9198.00 4952.00 1890.00  61.83  410.42
335      . 5.65  238.0 1866.00 1322.00 1414.00 5814.00 2534.00 1212.00  52.17  399.78
343      . 1.19  228.0 1186.00 2032.00  368.00 4254.00 2700.00  668.00  75.26  322.71
343      . 2.23  328.0 1684.00 3984.00  744.00 7374.00 4946.00  962.00  80.55  299.70
343      . 2.31  328.0 1560.00 3608.00  666.00 6724.00 4498.00  890.00  80.21  346.23
343      . 0.90  316.0 1576.00 3686.00  240.00 6572.00 4756.00 1070.00  77.50  375.45
-1
```

Table 23 Continued. File "*CCPA8629.BNB.*"

```
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  2
11 1 2 3 4 5 6 7 8 9 13 14
289    4.3 1.26    0.0  140.00     0.00  352.00  492.00    0.00     0.00      .   357.50
289    4.4 1.34    0.0  160.00     0.00  358.00  518.00    0.00     0.00      .   375.68
289    4.3 1.00    0.0  122.00     0.00  272.00  394.00    0.00     0.00      .   368.29
289    4.5 1.38    0.0  154.00     0.00  356.00  510.00    0.00     0.00      .   388.72
296      . 2.22    0.0  364.00     0.00  692.00 1056.00    0.00     0.00      .   320.56
296      . 2.98    0.0  584.00     0.00  908.00 1492.00    0.00     0.00      .   327.75
296      . 3.16    0.0  522.00     0.00  834.00 1356.00    0.00     0.00      .   379.09
296      . 3.24    0.0  540.00     0.00  890.00 1430.00    0.00     0.00      .   364.46
305      . 4.96    0.0 1188.00     0.00 1156.00 2344.00    0.00     0.00      .   429.29
305      . 5.18    0.0 1208.00     0.00 1294.00 2502.00    0.00     0.00      .   400.44
305      . 4.51    0.0  846.00     0.00  990.00 1836.00    0.00     0.00      .   455.69
305      . 4.84    0.0  976.00     0.00 1080.00 2056.00    0.00     0.00      .   447.71
311      . 3.61   86.0 1508.00     0.00 1612.00 3128.00    8.00     8.00   0.00  223.69
311      . 6.86   84.0 1762.00     0.00 1576.00 3344.00    6.00     6.00   0.00  435.08
311      . 3.41  104.0 1502.00     0.00 1578.00 3086.00    6.00     6.00   0.00  215.86
311      . 4.11  100.0 1664.00     0.00 1788.00 3458.00    6.00     6.00   0.00  229.65
316      . 7.73  450.0 2058.00     0.00 1660.00 3946.00  228.00   228.00   0.00  465.44
316      . 7.35  374.0 2098.00     0.00 1606.00 3900.00  196.00   196.00   0.00  457.72
316      . 6.41  484.0 1990.00     0.00 1422.00 3718.00  306.00   306.00   0.00  450.78
316      . 7.23  466.0 2224.00     0.00 1768.00 4248.00  256.00   256.00   0.00  408.74
328      . 5.11  468.0 1896.00  1300.00 1320.00 5842.00 2626.00  1326.00  49.50  386.99
328      . 4.44  384.0 1812.00   932.00 1186.00 4936.00 1938.00  1006.00  48.09  374.12
328      . 6.80  304.0 2456.00   962.00 1724.00 6714.00 2534.00  1572.00  37.96  394.19
328      . 5.91  470.0 2032.00   924.00 1370.00 5384.00 1982.00  1058.00  46.62  431.11
335      . 3.60  414.0 1836.00  2430.00 1000.00 6372.00 3536.00  1106.00  68.72  359.73
335      . 4.66  448.0 2388.00  3154.00 1298.00 8504.00 4818.00  1664.00  65.46  358.78
335      . 5.39  318.0 2312.00  1822.00 1556.00 7022.00 3154.00  1332.00  57.77  346.42
335      . 6.72  330.0 2326.00  2162.00 1424.00 7494.00 3744.00  1582.00  57.75  471.56
343      . 1.64  398.0 1954.00  4178.00  626.00 7890.00 5310.00  1132.00  78.68  261.72
343      . 1.06  276.0 1624.00  3008.00  218.00 5794.00 3952.00   944.00  76.11  485.29
343      . 1.47  442.0 2142.00  5124.00  358.00 9042.00 6542.00  1418.00  78.32  410.33
343      . 1.93  454.0 2106.00  4506.00  606.00 8508.00 5796.00  1290.00  77.74  319.00
-1
```

Table 24 File "*CCPA8629.BNC.*"

```
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  1
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  2
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  3
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  4
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  5
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  6
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  7
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  8
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO:  9
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO: 10
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO: 11
-1
 INST_ID :CC  SITE_ID: PA  EXPT_NO: 29  YEAR : 1986  TRT_NO: 12
-1
```

FILED - Measured Soil and Plant Nitrogen

Table 25 File "*UFGA8601.BND.*"

```
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  1
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  2
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  3
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  4
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  5
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  6
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  7
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  8
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  9
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO: 10
-1
```

Table 26 File "*UFGA8601.BNP*" (Data for only the first six treatments are shown).

```
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  1
3 9 10 11
093. 0.04 0.044   .
098. 0.09 0.055   .
105. 0.27 0.071   .
112. 0.52 0.089   .
119. 1.43 0.158   .
126. 2.62 0.359   .
133. 4.09 0.682   .
140. 4.56 0.928   .
147. 4.93 1.021   .
154. 4.65 0.953   .
161. 1.93 0.821   .
168. 1.25 0.977   .
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  2
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  3
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  4
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  5
1 9
093.  0.04
098.  0.10
105.  0.24
112.  0.34
119.  0.69
126.  0.59
133.  0.56
140.  0.64
147.  0.82
154.  0.85
161.  0.74
168.  1.94
-1
 INST_ID :UF  SITE_ID: GA  EXPT_NO: 01  YEAR : 1986  TRT_NO:  6
3 9 10 11
093.  0.04  0.048  .
098.  0.10  0.060  .
105.  0.27  0.074  .
112.  0.63  0.098  .
119.  1.51  0.176  .
126.  3.06  0.365  .
133.  5.21  0.710  .
140.  3.90  0.644  .
147.  4.05  0.732  .
154.  3.24  0.791  .
161.  2.09  0.775  .
168.  1.19  0.784  .
-1
```

Appendix E
GRAPHICS LABEL FILES

Crop Data Labels

Table 27 File "*GLABEL.DAT.*"

```
1. Vegetative Growth Stage
V-STAGE
2. Leaf Area Index
LAI
3. Number of Pods #/m2
POD NO-M2
4. Stem Dry Weight (kg/ha)
STEM-kg/ha
5. Seed Dry Weight (kg/ha)
SEED-kg/ha
6. Leaf Dry Weight (kg/ha)
LEAF-kg/ha
7. Canopy Dry Weight (kg/ha)
CANOPY WT
8. Pod Dry Weight (kg/ha)
POD-kg/ha
9. Shell Dry Weight (kg/ha)
SHELL-kg/ha
10.Root Dry Weight (kg/ha)
ROOT-kg/ha
11.Number of Seeds #/m2
SEED no-m2
12.Harvest Index (Seed/Top)
HARVEST IND
13.Shelling % (Seed/Pod*100)
SHELLING-%
14.Specific Leaf Area (cm2/g)
SLA cm2/g
15.Seed Size (mg/seed)
SEED SZ-mg
16.Nitrogen % in Canopy
NITROGEN-%
17.Relative Drought Stress Indicator
TURFAC
18.Canopy Height (m)
CAN HT-m
19.Canopy Width (m)
CAN WDTH-m
20.Root Length Density Layer 1 cm/cm3
Root LD L1
21.Root Length Density Layer 2 cm/cm3
Root LD L2
22.Root Length Density Layer 3 cm/cm3
Root LD L3
23.Root Length Density Layer 4 cm/cm3
Root LD L4
24.Root Length Density Layer 5 cm/cm3
Root LD L5
25.Root Length Density Layer 6 cm/cm3
Root LD L6
```

Soil Water and Weather Data Labels

Table 28 File "*GLABEL2.DAT.*"

```
1. Avg. Transpiration (mm)
TRANSP-mm
2. Avg. Soil & Plant Evaporation (mm)
EVAP - mm
3. Avg. Pot. Evapotranspiration (mm)
POT ET-mm
4. Solar Radiation (MJ)
RAD - MJ
5. Daylength (h)
DAYL - h
6. Maximum Air Temperature (C)
MAX T - C
7. Minimum Air Temperature (C)
MIN T - C
8. Rainfall (mm)
RAIN - mm
9. Irrigation (mm)
IRRIG - mm
10.Runoff (mm)
RUNOFF-mm
11.Drainage (mm)
DRAIN-mm
12 Soil Evaporation (mm)
EVAP - mm
13 Transpiration (mm)
TRANSP-mm
14 Evapo-Transpiration (mm)
ET-mm
15.Extractable Soil Water (mm)
PESW - mm
16.Soil Water Content Layer 1 cm3/cm3
SWC L1
17.Soil Water Content Layer 2 cm3/cm3
SWC L2
18.Soil Water Content Layer 3 cm3/cm3
SWC L3
19.Soil Water Content Layer 4 cm3/cm3
SWC L4
20.Soil Water Content Layer 5 cm3/cm3
SWC L5
21.Soil Water Content Layer 6 cm3/cm3
SWC L6
22.Soil Water Content Layer 7 cm3/cm3
SWC L7
23.Soil Water Content Layer 8 cm3/cm3
SWC L8
24.Soil Water Content Layer 9 cm3/cm3
SWC L9
25.Soil Water Content Layer 10 cm3/cm3
SWC L10
```

Plant Nitrogen Data Labels

Table 29 File "*GLABEL3.DAT.*"

```
01.Nitrogen % in Leaves
LEAF-%N
02.Nitrogen % in Stems
STEM-%N
03.Nitrogen % in Roots
ROOT-%N
04.Nitrogen % in Shells
SHELL-%N
05.Nitrogen % in Seeds
SEED-%N
```

Photosynthesis Data Labels

Table 30 File "*GLABELP.DAT.*"

```
1. Daily Phot. Synth. Active Rad.(E)
PAR - E/d
2. Phot. Synth. Act. Rad. at 12.00
PAR-noon
3. Fraction Diffuse Rad. at 12.00
FRDIF-noon
4. Light Interception at 12.00
INTERC-%
5. Gross Daily Can. Photosynthesis
PGCAN-gCO2
6. Old Gross Daily Can. Photosynthesis
PGOLD-gCO2
7. Canopy Photosynthesis at 12.00
PG12-mgCO2
8. Max. Leaf Photosynthetic Rate
LFMX-mgCO2
9. Leaf Area Index
LAI
10.Canopy Height (m)
CAN HT-m
11.Canopy Width (m)
CAN WITH-m
12.Nitrogen % in Canopy
NITROGEN-%
13.Relative Drought Stress Indicator
SWFAC
14.Vegetative Growth Stage
V-STAGE
```

Harvest and Developmental Summary Data Labels

Table 31 File "*GLABEL4.DAT*."

```
15 14 7 8
-1 -1 -1 -1 -1 1 -1 -1 -1 -1 -1 1 1 1 1
2. Sowing-Flowering Duration
3. Sowing-Maturity Duration
4. Total N-loss,kg/ha
5. Nitrogen stress in vegetative stage
6. Nitrogen stress in reproductive stage
7. Total Nitrogen uptake,kg/ha
8. Number of irrigations
9. Cumulative Irrigation-mm
10 Water stress in vegetative stage
11 Water stress in reproductive stage
12 Total Evapo-transpiration-mm
13 Total Rainfall,mm
14 Total Biomass,t/ha
15 Grain Yield,t/ha
16 Pod yield,t/ha
```

Appendix F
OUTPUT FILES

OUT1 : Output Echo and Summary

Table 32 File "*OUT1.BN.*"

```
                                  BEANGRO V1.01
                                  =============

INPUT SUMMARY      RUN NO.  1          SIMULATION BEGINS : AUG 27

INST_ID: CC  SITE_ID: PA  EXPT_NO: 29  YEAR: 1986  TRT_NO:  1
EXPERIMENT    : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT     : Porrillo Sin.  0.3 m row by 15 pl/m2
WEATHER SET   : CIAT, PALMIRA, COLOMBIA      1986
VARIETY       : Porrillo Sintetico    PHOTOPERIOD GRP :  3 TEMPERATURE GRP :  1
IRRIGATION    : ACCORDING TO THE FIELD SCHEDULE
PLANTING DATE: SEP 26 PLANTS/M2: 15.00 ROW SPACING: .300m PLANT SPACING: .222m

SOIL PROFILE DATA  Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
SOIL ALBEDO   :  .09  U:11.0  SWCON:  .40  CURVE NO.: 84.0  PHFAC3:1.00
  DEPTH-m      LL     DUL    SAT   EXTR   INIT   ROOT   SWCN
  .00-  .05  .204    .340   .392   .136   .340  1.000   .000
  .05-  .15  .204    .340   .392   .136   .340  1.000   .000
  .15-  .25  .209    .345   .390   .136   .345   .750   .000
  .25-  .35  .209    .345   .390   .136   .345   .500   .000
  .35-  .50  .198    .335   .390   .137   .335   .350   .000
  .50-  .65  .185    .323   .395   .138   .323   .200   .000
  .65-  .80  .185    .323   .395   .138   .323   .150   .000
  .80-  .99  .201    .328   .408   .127   .328   .100   .000
  .99- 1.22  .198    .325   .410   .127   .325   .050   .000
 1.22- 1.37  .159    .288   .399   .129   .288   .000   .000
 1.37- 1.59  .110    .242   .402   .132   .242   .000   .000
 1.59- 1.84  .047    .177   .351   .130   .177   .000   .000
 1.84- 2.09  .050    .193   .410   .143   .193   .000   .000
             ----------------------------------
   SUM mm   313.6   593.2  824.2  279.5  593.2

  RUN NO.  1          SIMULATION OUTPUT

  CC  PA  1986        Porrillo 1986

                                             WATER BALANCE COMPONENTS    DROUGHT
  DATE CROP GROWTH     BIOMASS   LAI    V-  ES    EP    ET    RAIN IRRIG    STRESS
        AGE STAGE       KG/HA         STAGE mm    mm    mm     mm     mm  PHOTO TURGOR
---------------------------------------------------------------------------------------
SEP 26    0 SOWING          0.   .00    .0  51.    0.   51.    70.    30.  .000  .000
SEP 30    4 EMERGENCE      11.   .02    .0  69.    0.   69.    92.    30.  .000  .000
SEP 30    4 END JUVEN.     11.   .02    .0  69.    0.   69.    92.    30.  .000  .000
OCT  6   10 FLOWER IND     24.   .05    .9  95.    0.   95.   124.    30.  .000  .000
OCT  7   11 UNIFOLIOL.     28.   .07   1.0  99.    0.   99.   137.    30.  .000  .000
NOV  3   38 FLOWERING    1918.  4.07   8.3 155.   42.  196.   276.    30.  .000  .031
NOV  8   43 FIRST POD    2778.  5.32   9.7 157.   58.  216.   324.    30.  .000  .000
NOV 15   50 FULL POD     4187.  5.99  11.8 160.   85.  245.   327.    30.  .000  .000
NOV 16   51 FIRST SEED   4436.  6.08  12.1 161.   89.  250.   327.    30.  .000  .000
NOV 16   51 END MSNODE   4436.  6.08  12.1 161.   89.  250.   327.    30.  .000  .000
NOV 21   56 END POD      5442.  5.60  12.1 162.  107.  270.   329.    55.  .000  .000
NOV 26   61 END LEAF     6363.  4.88  12.1 165.  125.  290.   355.    55.  .000  .000
NOV 30   65 PHYS. MAT    6920.  4.30  12.1 166.  136.  302.   368.    55.  .000  .000
DEC  9   74 HARV. MAT    6037.   .28  12.1 184.  154.  338.   375.    55.  .000  .000
```

Table 32 Continued. File "*OUT1.BN.*"

```
  RUN NO.  1

  CC  PA  1986           Porrillo 1986

                         PREDICTED    MEASURED
                         ---------    --------
FLOWERING DATE             307          307
FIRST POD                  312            0
FULL POD                   319            0
PHYSIOL. MATURITY          334          341
POD YLD (KG/HA)          4417.00      4225.00
SEED YLD (KG/HA)         3368.00      3328.00
SHELLING PERCENTAGE        76.24        78.77
WT. PER SEED (G)            .198         .188
SEED NUMBER (SEED/M2)    1699.00      1768.00
SEEDS/POD                   5.20         5.89
MAXIMUM LAI                 6.10         6.61
BIOMASS (KG/HA) AT R8    6037.00      6231.00
STALK (KG/HA) AT R8      1532.00      1502.00
HARVEST INDEX               .558         .534

[Seed YLD and HI on DRYWEIGHT BASIS]

          Irrigation Summary
          ==================

 2 IRRIGATION APPLICATIONS @  1.00 EFFICIENCY.

CROP AGE     0   55
AMOUNT,mm  30.  25.

        DRY BEAN YIELD :  3367.8 KG/HA [ 3006.0 LBS/ACRE ]
```

Table 33 File "*OUT2.BN.*"

BEANGRO V1.01
****

```
RUN  1          Porrillo 1986
INST_ID: CC  SITE_ID: PA  EXPT_NO: 29  YEAR: 1986  TRT_NO:  1
EXPERIMENT    : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT     : Porrillo Sin.  0.3 m row by 15 pl/m2
WEATHER SET   : CIAT, PALMIRA, COLOMBIA       1986
SOIL TYPE     : Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
VARIETY       : Porrillo Sintetico     PHOTOPERIOD GROUP :  3
IRRIGATION    : ACCORDING TO THE FIELD SCHEDULE
```

JUL DAY	VST- AGE	LAI	PODS NO	STEM WT	SEED WT	LEAF WT	CANO- WT	POD WT	SHELL WT	=>
269	.00	.00	.0	.0	.0	.0	.0	.0	.0	=>
270	.00	.00	.0	.0	.0	.0	.0	.0	.0	=>
272	.00	.00	.0	.0	.0	.0	.0	.0	.0	=>
274	.16	.02	.0	3.8	.0	8.8	12.6	.0	.0	=>
276	.44	.03	.0	4.7	.0	11.0	15.7	.0	.0	=>
278	.73	.04	.0	6.3	.0	14.5	20.8	.0	.0	=>
280	1.03	.07	.0	8.6	.0	19.7	28.3	.0	.0	=>
282	1.55	.10	.0	11.9	.0	27.0	38.8	.0	.0	=>
284	2.07	.15	.0	17.4	.0	39.0	56.3	.0	.0	=>
286	2.64	.22	.0	26.9	.0	59.3	86.2	.0	.0	=>
288	3.18	.34	.0	39.9	.0	86.3	126.2	.0	.0	=>
290	3.72	.49	.0	61.7	.0	130.6	192.3	.0	.0	=>
292	4.27	.73	.0	93.2	.0	192.5	285.7	.0	.0	=>
294	4.80	1.05	.0	140.3	.0	280.7	421.1	.0	.0	=>
296	5.28	1.32	.0	196.8	.0	377.7	574.5	.0	.0	=>
298	5.84	1.83	.0	280.3	.0	507.2	787.5	.0	.0	=>
300	6.39	2.40	.0	382.4	.0	650.3	1032.7	.0	.0	=>
302	6.94	2.92	.0	484.7	.0	766.3	1251.0	.0	.0	=>
304	7.50	3.44	.0	639.8	.0	919.5	1559.3	.0	.0	=>
306	7.99	3.78	.0	765.4	.0	1007.2	1772.6	.0	.0	=>
308	8.57	4.39	.0	948.6	.0	1152.8	2101.3	.0	.0	=>
310	9.13	4.89	.0	1152.0	.0	1304.3	2456.3	.0	.0	=>
312	9.72	5.32	32.1	1345.2	.0	1432.4	2777.6	.0	.0	=>
314	10.30	5.61	97.9	1556.8	.0	1561.2	3157.6	39.6	39.6	=>
316	10.92	5.79	164.1	1747.8	.0	1661.9	3539.4	129.8	129.8	=>
318	11.50	5.88	230.4	1917.5	.0	1745.8	3939.0	275.8	275.8	=>
320	12.10	6.08	299.9	2095.8	.0	1870.7	4436.1	469.6	469.6	=>
322	12.10	6.00	360.6	2148.2	91.1	1870.1	4832.3	813.9	722.8	=>
324	12.10	5.74	430.3	2170.0	301.6	1813.1	5263.0	1279.9	978.4	=>
326	12.10	5.45	429.4	2136.9	630.4	1721.9	5629.0	1770.1	1139.7	=>
328	12.10	5.17	423.1	2103.8	1094.6	1630.8	5998.7	2264.1	1169.5	=>
330	12.10	4.88	392.3	2070.7	1630.7	1539.7	6363.1	2752.7	1122.0	=>
332	12.10	4.59	326.7	2037.6	1997.9	1448.5	6584.3	3098.1	1100.2	=>
334	12.10	4.30	326.7	2004.5	2467.9	1357.4	6920.1	3558.2	1090.3	=>
336	12.10	2.36	326.7	1814.8	2916.3	745.0	6556.4	3996.7	1080.4	=>
338	12.10	1.28	326.7	1705.7	3209.7	403.7	6389.6	4280.2	1070.5	=>
340	12.10	.67	326.7	1641.5	3344.7	212.9	6260.9	4406.5	1061.8	=>
342	12.10	.37	326.7	1571.1	3361.0	116.8	6102.4	4414.5	1053.5	=>
343	12.10	.28	326.7	1532.5	3367.8	87.6	6037.2	4417.2	1049.3	=>

Table 33 Continued. File "*OUT2.BN.*"

ROOT WT	SEED NO	HARVEST IND	SHELL %	SLA	SEED SIZE	NIT %	WATER STRESS	CANHT	CANWH	=>
.0	.0	.000	.0	.0	.0	.00	1.00	.00	.00	=>
.0	.0	.000	.0	.0	.0	.00	1.00	.00	.00	=>
.0	.0	.000	.0	.0	.0	.00	1.00	.00	.00	=>
12.2	.0	.000	.0	249.1	.0	3.36	1.00	.05	.03	=>
14.2	.0	.000	.0	278.5	.0	3.36	1.00	.06	.04	=>
17.0	.0	.000	.0	304.5	.0	3.36	1.00	.07	.04	=>
20.3	.0	.000	.0	333.8	.0	3.36	1.00	.08	.05	=>
23.3	.0	.000	.0	358.6	.0	3.36	1.00	.09	.06	=>
26.9	.0	.000	.0	373.7	.0	3.36	1.00	.09	.08	=>
32.0	.0	.000	.0	376.0	.0	3.36	1.00	.11	.10	=>
37.6	.0	.000	.0	399.7	.0	3.36	1.00	.12	.12	=>
53.5	.0	.000	.0	373.9	.0	3.36	.89	.14	.16	=>
68.6	.0	.000	.0	380.1	.0	3.36	.90	.16	.19	=>
93.9	.0	.000	.0	375.3	.0	3.36	.86	.19	.23	=>
158.9	.0	.000	.0	349.0	.0	3.36	.71	.21	.26	=>
181.1	.0	.000	.0	360.5	.0	3.36	1.00	.25	.30	=>
208.3	.0	.000	.0	368.8	.0	3.36	1.00	.30	.30	=>
234.5	.0	.000	.0	381.5	.0	3.36	1.00	.35	.30	=>
272.3	.0	.000	.0	374.1	.0	3.36	1.00	.41	.30	=>
299.9	.0	.000	.0	375.1	.0	3.36	1.00	.46	.30	=>
336.0	.0	.000	.0	381.0	.0	3.36	1.00	.51	.30	=>
373.1	.0	.000	.0	374.7	.0	3.36	1.00	.58	.30	=>
405.4	.0	.000	.0	371.4	.0	3.36	1.00	.64	.30	=>
439.0	.0	.000	.0	359.5	.0	3.36	1.00	.72	.30	=>
465.7	.0	.000	.0	348.1	.0	3.36	1.00	.80	.30	=>
484.6	.0	.000	.0	336.8	.0	3.36	1.00	.87	.30	=>
500.8	164.9	.000	.0	325.3	.0	3.36	1.00	.95	.30	=>
495.0	502.1	.019	11.2	320.8	18.2	3.35	1.00	1.03	.30	=>
487.5	841.6	.057	23.6	316.8	35.8	3.29	1.00	1.07	.30	=>
469.3	1181.9	.112	35.6	316.8	53.3	3.21	1.00	1.07	.30	=>
451.8	1512.7	.182	48.3	316.8	72.4	3.12	1.00	1.07	.30	=>
435.6	1672.8	.256	59.2	316.8	97.5	3.02	1.00	1.07	.30	=>
420.7	1699.0	.303	64.5	316.8	117.6	2.91	1.00	1.07	.30	=>
406.3	1699.0	.357	69.4	316.8	145.3	2.78	1.00	1.07	.30	=>
391.7	1699.0	.445	73.0	316.8	171.7	2.60	1.00	1.07	.30	=>
377.8	1699.0	.502	75.0	316.8	188.9	2.30	1.00	1.07	.30	=>
362.8	1699.0	.534	75.9	316.8	196.9	1.79	1.00	1.07	.30	=>
345.7	1699.0	.551	76.1	316.8	197.8	1.12	1.00	1.07	.30	=>
337.2	1699.0	.558	76.2	316.8	198.2	1.12	1.00	1.07	.30	=>

Table 32 Continued. File "*OUT2.BN.*"

ROOT LENGTH DENSITY

L1	L2	L3	L4	L5	L6
.04	.04	.04	.00	.00	.00
.04	.04	.04	.00	.00	.00
.04	.04	.04	.00	.00	.00
.04	.04	.04	.00	.00	.00
.04	.05	.04	.00	.00	.00
.04	.06	.05	.01	.00	.00
.05	.07	.06	.01	.00	.00
.06	.08	.07	.02	.00	.00
.07	.09	.07	.02	.00	.00
.07	.10	.08	.03	.01	.00
.07	.12	.09	.04	.02	.00
.06	.15	.12	.06	.03	.00
.10	.18	.14	.07	.04	.01
.13	.22	.17	.10	.06	.01
.11	.34	.26	.15	.10	.03
.25	.47	.36	.22	.15	.06
.32	.53	.40	.25	.17	.07
.40	.61	.46	.29	.19	.09
.47	.67	.51	.32	.22	.10
.54	.73	.56	.35	.24	.12
.63	.82	.62	.40	.27	.14
.72	.90	.68	.44	.30	.15
.80	.98	.74	.48	.33	.17
.89	1.05	.80	.52	.35	.19
.97	1.13	.85	.55	.38	.20
1.01	1.17	.88	.57	.39	.21
1.06	1.21	.91	.59	.41	.22
1.09	1.23	.93	.60	.42	.22
1.06	1.20	.90	.59	.41	.22
1.03	1.16	.88	.57	.39	.21
.99	1.12	.84	.55	.38	.20
.96	1.08	.81	.53	.37	.20
.92	1.04	.79	.51	.35	.19
.89	1.01	.76	.50	.34	.18
.86	.97	.73	.48	.33	.18
.83	.94	.71	.46	.32	.17
.78	.90	.68	.44	.31	.16
.68	.87	.65	.43	.29	.16
.63	.85	.64	.42	.29	.16

OUT3 : Soil Water and Weather Data

Table 34 File "*OUT3.BN.*"

BEANGRO V1.01
============

RUN 1 Porrillo 1986
INST_ID: CC SITE_ID: PA EXPT_NO: 29 YEAR: 1986 TRT_NO: 1
EXPERIMENT : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT : Porrillo Sin. 0.3 m row by 15 pl/m2
WEATHER SET : CIAT, PALMIRA, COLOMBIA 1986
SOIL TYPE : Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
VARIETY : Porrillo Sintetico PHOTOPERIOD GROUP : 3
IRRIGATION : ACCORDING TO THE FIELD SCHEDULE

JUL	------------			DAILY	-------------			-----------------			PERIOD	-----------------			=>
DAY	EP	ET	EO	SR	PHOTOP	MAX	MIN	RAIN	IRRIG	RUNOFF	DRAIN	CES	CEP	CET	=>
239	.0	5.4	5.4	19.80	12.08	31.5	17.7	20.8	.0	2.1	.0	5.4	.0	5.4	=>
240	.0	5.8	6.0	22.00	12.08	31.0	18.2	20.8	.0	2.1	6.4	11.2	.0	11.2	=>
242	.0	1.1	5.1	18.90	12.07	30.0	19.5	21.1	.0	2.1	9.9	14.3	.0	14.3	=>
244	.0	.7	3.9	14.50	12.06	28.8	19.2	21.3	.0	2.1	11.5	16.0	.0	16.0	=>
246	.0	5.1	5.1	18.90	12.06	29.5	18.7	52.9	.0	4.2	11.5	22.4	.0	22.4	=>
248	.0	4.6	5.9	22.10	12.05	30.8	16.5	53.9	.0	4.2	17.9	31.3	.0	31.3	=>
250	.0	.8	5.7	21.00	12.04	31.5	18.5	53.9	.0	4.2	22.9	33.1	.0	33.1	=>
252	.0	.6	5.6	20.30	12.04	32.7	18.4	53.9	.0	4.2	24.0	34.4	.0	34.4	=>
254	.0	.5	3.5	12.80	12.03	29.5	20.0	53.9	.0	4.2	24.0	35.5	.0	35.5	=>
256	.0	.5	5.4	19.50	12.03	31.5	19.8	53.9	.0	4.2	24.0	36.5	.0	36.5	=>
258	.0	.4	5.7	20.70	12.02	31.6	19.2	53.9	.0	4.2	24.0	37.4	.0	37.4	=>
260	.0	.4	5.3	19.30	12.01	30.9	19.0	53.9	.0	4.2	24.0	38.2	.0	38.2	=>
262	.0	.4	5.5	20.00	12.01	32.1	18.9	53.9	.0	4.2	24.0	39.0	.0	39.0	=>
264	.0	.4	5.7	21.00	12.00	30.5	19.1	54.0	.0	4.2	24.0	39.8	.0	39.8	=>
266	.0	.3	4.7	17.60	11.99	28.9	20.0	54.2	.0	4.2	24.0	40.7	.0	40.7	=>
268	.0	.4	4.3	16.40	11.99	28.6	18.8	59.0	.0	4.2	24.0	45.0	.0	45.0	=>
270	.0	4.2	4.2	16.20	11.98	27.4	17.1	70.9	30.0	9.0	24.0	55.5	.0	55.5	=>
272	.0	3.2	3.2	12.30	11.97	26.5	19.1	91.9	30.0	9.8	24.8	64.1	.0	64.1	=>
274	.0	6.1	6.2	22.50	11.97	31.0	20.5	99.0	30.0	9.8	35.8	75.0	.0	75.0	=>
276	.1	6.1	6.1	23.00	11.96	29.4	18.5	107.8	30.0	9.8	42.5	83.5	.1	83.6	=>
278	.2	4.6	6.2	23.00	11.95	30.7	19.0	112.0	30.0	9.8	43.2	90.4	.3	90.7	=>
280	.1	4.2	4.2	15.90	11.95	28.3	18.9	136.7	30.0	9.8	44.2	98.9	.5	99.4	=>
282	.1	2.2	2.2	8.90	11.94	23.9	16.0	159.4	30.0	12.1	45.4	105.5	.7	106.2	=>
284	.2	3.0	3.0	11.80	11.93	25.0	19.4	162.1	30.0	12.1	47.0	112.8	1.0	113.8	=>
286	.4	3.3	4.5	17.40	11.93	28.1	18.5	165.6	30.0	12.1	49.0	119.6	1.9	121.5	=>
288	.3	2.8	2.8	11.20	11.92	26.0	18.8	169.0	30.0	12.1	51.7	124.4	2.6	127.0	=>
290	1.1	3.7	5.2	20.10	11.92	30.1	19.0	172.3	30.0	12.1	60.7	128.5	4.6	133.1	=>
292	1.4	3.3	4.5	17.80	11.91	28.1	19.7	179.1	30.0	12.1	65.5	133.1	6.7	139.8	=>
294	1.7	4.4	4.4	18.00	11.90	28.7	18.0	182.7	30.0	12.1	66.7	137.8	9.6	147.4	=>
296	2.8	4.0	5.0	20.20	11.90	30.0	20.5	182.7	30.0	12.1	67.9	140.6	14.4	154.9	=>
298	2.4	4.6	4.6	19.30	11.89	28.0	17.8	219.6	30.0	13.3	67.9	144.7	18.4	163.2	=>
300	2.6	4.3	4.3	18.60	11.89	28.1	18.2	220.8	30.0	13.3	67.9	147.9	23.0	170.9	=>
302	1.4	2.0	2.0	9.00	11.88	25.1	18.2	223.9	30.0	13.3	67.9	150.1	27.4	177.5	=>
304	3.7	4.9	4.9	21.40	11.88	28.8	18.0	242.1	30.0	13.3	67.9	152.6	34.3	186.9	=>

Table 33 Continued. File "*OUT3.BN.*"

306	3.7	4.7	4.7	21.10	11.87	28.5	15.0	269.0	30.0	16.2	68.2	154.0	39.1	193.1	=>
308	3.6	4.3	4.3	18.70	11.87	29.1	19.2	301.6	30.0	22.1	69.0	155.4	45.2	200.7	=>
310	4.2	4.8	4.8	21.10	11.86	30.0	16.5	301.6	30.0	22.1	92.8	156.6	52.2	208.8	=>
312	3.6	4.1	4.1	17.60	11.86	29.0	19.4	324.1	30.0	22.9	93.6	157.5	58.1	215.6	=>
314	3.9	4.3	4.3	18.90	11.85	29.2	18.2	325.8	30.0	22.9	101.9	158.3	65.4	223.8	=>
316	3.5	3.9	3.9	16.30	11.85	30.4	20.5	327.3	30.0	22.9	105.2	159.1	73.2	232.3	=>
318	4.8	5.2	5.2	22.60	11.84	30.0	17.8	327.3	30.0	22.9	106.0	159.9	81.0	240.9	=>
320	4.2	4.6	4.6	19.70	11.84	30.5	18.0	327.3	30.0	22.9	106.0	160.7	89.4	250.1	=>
322	2.4	2.6	2.6	11.60	11.83	25.8	19.6	328.5	30.0	22.9	106.0	161.3	96.0	257.2	=>
324	3.9	4.3	4.3	18.40	11.83	30.5	19.0	328.6	55.0	23.7	106.0	162.0	104.2	266.2	=>
326	3.4	3.7	3.7	15.90	11.83	29.4	20.0	337.7	55.0	23.7	106.0	162.7	110.7	273.3	=>
328	3.8	4.3	4.3	18.60	11.82	28.6	19.0	354.8	55.0	25.1	106.0	163.5	117.6	281.1	=>
330	4.1	4.7	4.7	20.30	11.82	30.0	17.9	354.8	55.0	25.1	106.0	164.5	125.3	289.8	=>
332	3.0	3.5	3.5	15.40	11.82	27.0	18.5	365.7	55.0	25.1	106.0	165.2	129.3	294.5	=>
334	2.4	2.9	2.9	12.70	11.81	27.4	19.3	367.6	55.0	25.1	106.0	166.3	135.9	302.2	=>
336	2.7	3.6	3.6	15.60	11.81	28.2	18.0	367.6	55.0	25.1	106.0	168.0	142.7	310.8	=>
338	2.7	5.0	5.0	20.40	11.81	30.6	18.6	372.0	55.0	25.1	106.0	171.4	147.5	319.0	=>
340	1.5	3.7	3.7	15.00	11.81	28.5	20.0	372.0	55.0	25.1	106.0	175.4	150.5	325.9	=>
342	.9	4.4	4.4	17.00	11.80	29.9	19.5	375.4	55.0	25.1	106.0	180.8	152.2	333.1	=>
343	1.6	4.5	4.7	17.80	11.80	30.0	19.9	375.4	55.0	25.1	106.0	183.7	153.9	337.6	=>

Table 34 Continued. File "*OUT3.BN.*"

TOTAL			SOIL WATER CONTENT W/DEPTH							
PESW	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10
292.9	.276	.365	.372	.372	.368	.338	.329	.330	.326	.288
280.7	.176	.347	.361	.361	.355	.332	.327	.330	.326	.288
274.3	.150	.330	.350	.353	.344	.330	.327	.330	.327	.288
271.3	.147	.320	.345	.349	.339	.327	.326	.330	.327	.290
294.3	.282	.365	.372	.372	.363	.337	.330	.332	.328	.291
280.1	.157	.337	.358	.360	.349	.334	.330	.332	.327	.290
273.2	.149	.325	.348	.350	.340	.327	.325	.330	.327	.290
270.9	.147	.317	.344	.347	.337	.325	.325	.330	.327	.290
269.7	.145	.310	.341	.346	.337	.325	.325	.330	.327	.290
268.8	.144	.305	.338	.345	.337	.325	.325	.330	.327	.290
267.9	.144	.301	.335	.343	.337	.325	.325	.330	.327	.290
267.0	.143	.297	.333	.342	.336	.325	.325	.330	.327	.290
266.3	.142	.293	.331	.341	.336	.325	.325	.330	.327	.290
265.5	.142	.290	.329	.340	.335	.325	.325	.330	.327	.290
264.9	.142	.288	.327	.339	.335	.325	.325	.330	.327	.290
265.4	.165	.285	.325	.338	.334	.325	.325	.330	.327	.290
291.9	.219	.347	.367	.370	.361	.343	.336	.334	.329	.292
302.8	.253	.348	.367	.370	.361	.358	.351	.344	.334	.297
287.4	.207	.330	.352	.357	.348	.341	.340	.339	.332	.295
281.5	.216	.330	.346	.350	.341	.332	.333	.335	.330	.294
277.8	.188	.319	.342	.347	.338	.329	.330	.335	.330	.295
292.8	.299	.366	.372	.362	.341	.328	.329	.333	.330	.295
305.3	.291	.349	.367	.370	.361	.359	.349	.342	.333	.298
298.8	.229	.330	.352	.361	.352	.348	.350	.347	.338	.303
292.6	.188	.317	.343	.351	.344	.339	.344	.346	.339	.307
287.7	.179	.308	.338	.346	.339	.332	.337	.342	.338	.308
276.0	.180	.295	.329	.342	.336	.326	.329	.335	.332	.299
271.3	.232	.286	.322	.337	.333	.325	.326	.331	.329	.294
266.1	.217	.276	.312	.331	.330	.324	.326	.330	.328	.291
257.4	.170	.264	.296	.320	.324	.321	.326	.330	.328	.290
284.8	.326	.362	.366	.350	.324	.319	.325	.330	.328	.290
278.3	.295	.330	.348	.349	.329	.318	.325	.330	.328	.290
274.8	.310	.315	.335	.340	.326	.316	.324	.330	.328	.290
283.5	.338	.360	.361	.348	.326	.314	.323	.330	.328	.290
301.0	.342	.360	.364	.367	.364	.356	.337	.334	.329	.291

Table 34 Continued. File "*OUT3.BN.*"

319.3	.348	.361	.364	.367	.365	.364	.366	.369	.342	.301
287.4	.311	.328	.339	.345	.340	.335	.338	.343	.331	.293
301.5	.353	.361	.364	.367	.352	.337	.337	.341	.334	.298
286.8	.329	.334	.344	.349	.339	.329	.330	.335	.331	.295
276.4	.324	.314	.327	.336	.330	.322	.324	.331	.328	.292
267.0	.290	.293	.311	.325	.322	.318	.322	.330	.327	.291
257.9	.262	.269	.293	.312	.314	.314	.320	.330	.327	.291
251.9	.263	.260	.278	.300	.306	.309	.318	.329	.327	.291
267.2	.354	.360	.328	.288	.296	.303	.314	.328	.327	.291
269.2	.356	.362	.353	.297	.290	.300	.313	.328	.327	.291
277.1	.331	.343	.349	.353	.331	.301	.311	.327	.327	.291
268.4	.301	.317	.332	.339	.326	.299	.309	.326	.327	.291
274.6	.338	.348	.340	.341	.329	.299	.308	.326	.327	.291
268.8	.329	.329	.331	.332	.322	.297	.307	.325	.327	.291
260.3	.285	.307	.317	.323	.315	.295	.305	.324	.327	.291
256.5	.296	.294	.307	.315	.309	.293	.304	.324	.326	.291
249.5	.223	.282	.300	.311	.306	.293	.303	.323	.326	.291
245.8	.192	.274	:296	.307	.304	.292	.303	.323	.326	.291
241.3	.140	.269	.291	.304	.301	.291	.303	.322	.326	.291

OUT4 : Crop Nitrogen (%)

Table 35 File "*OUT4.BN.*"

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                              BEANGRO V1.01
                              =============

RUN  1            Porrillo 1986
INST_ID: CC  SITE_ID: PA  EXPT_NO: 29  YEAR: 1986  TRT_NO:  1
EXPERIMENT    : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT     : Porrillo Sin.  0.3 m row by 15 pl/m2
WEATHER SET   : CIAT, PALMIRA, COLOMBIA      1986
SOIL TYPE     : Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
VARIETY       : Porrillo Sintetico    PHOTOPERIOD GROUP :  3
IRRIGATION    : ACCORDING TO THE FIELD SCHEDULE
```

JUL DAY	LEAF %N	STEM %N	ROOT %N	SHELL %N	SEED %N
269	.00	.00	.00	.00	.00
270	.00	.00	.00	.00	.00
272	.00	.00	.00	.00	.00
274	3.36	1.92	1.60	.00	.00
276	3.36	1.92	1.60	.00	.00
278	3.36	1.92	1.60	.00	.00
280	3.36	1.92	1.60	.00	.00
282	3.36	1.92	1.60	.00	.00
284	3.36	1.92	1.60	.00	.00
286	3.36	1.92	1.60	.00	.00
288	3.36	1.92	1.60	.00	.00
290	3.36	1.92	1.60	.00	.00
292	3.36	1.92	1.60	.00	.00
294	3.36	1.92	1.60	.00	.00
296	3.36	1.92	1.60	.00	.00
298	3.36	1.92	1.60	.00	.00
300	3.36	1.92	1.60	.00	.00
302	3.36	1.92	1.60	.00	.00
304	3.36	1.92	1.60	.00	.00
306	3.36	1.92	1.60	.00	.00
308	3.36	1.92	1.60	.00	.00
310	3.36	1.92	1.60	.00	.00
312	3.36	1.92	1.60	.00	.00
314	3.36	1.92	1.60	3.20	.00
316	3.36	1.92	1.60	3.20	.00
318	3.36	1.92	1.60	3.20	.00
320	3.36	1.92	1.60	3.20	.00
322	3.32	1.88	1.60	3.15	3.68
324	3.25	1.81	1.60	3.06	3.68
326	3.16	1.74	1.60	2.97	3.68
328	3.07	1.66	1.60	2.87	3.68
330	2.97	1.58	1.60	2.75	3.68
332	2.85	1.50	1.60	2.63	3.68
334	2.71	1.42	1.60	2.51	3.68
336	2.47	1.33	1.60	2.38	3.68
338	2.08	1.23	1.60	2.25	3.68
340	1.40	1.12	1.60	1.87	3.68
342	1.12	1.02	1.60	1.75	3.68
343	1.12	.97	1.60	1.70	3.68

OUT5 : Harvest and Developmental Summary Data

Table 36 File "*OUT5.BN.*"

```
    FLO MAT TLOSS  NSV  NSR TOnup NIR IRRmm  WSV  WSR  CET CRAIN   =>
BN:  38  65    0.  .00  .00    .0   2   55.  .00  .00 338.  375   =>

BIOM YIELD PDYLD PLTPOP  NF  N-kg  TITLE                         =>
6.04  3.37  4.42  15.00   0     0. Porrillo 1986                 =>

RUN IN SI YEAR EX TR IR CULTIVAR WEATHER FILE SOIL TYPE    ROWSP  =>
  1 CC PA 1986 29  1  2 Porrillo CCPA0112.W86 Palmira (M3N   .300  =>

N-LAI STEMW SDSZ  SDNO  SDPOD  SH%   HI SIM PLT
 6.10  1.53  .20  1699.  5.20  76.  .56 239 269
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Table 37 File "*OUTP.BN.*"

```
                              BEANGRO V1.01
                              =============

RUN  1           Porrillo 1986
INST_ID: CC  SITE_ID: PA  EXPT_NO: 29  YEAR: 1986  TRT_NO:  1
EXPERIMENT    : 3 CULTIVARS, 2 ROW WIDTHS, 2 DENSITIES
TREATMENT     : Porrillo Sin.  0.3 m row by 15 pl/m2
WEATHER SET   : CIAT, PALMIRA, COLOMBIA      1986
SOIL TYPE     : Silty Clay Loam(Fine-silty,mixed,isohyperth.Aquic Hapludoll)
VARIETY       : Porrillo Sintetico    PHOTOPERIOD GROUP :  3
IRRIGATION    : ACCORDING TO THE FIELD SCHEDULE
```

JUL DAY	PAR E/day	PAR-12 uME/s	FRDIF	INTCT	PHOTG gCO2/d	PGOLD gCO2/d	PG-12 mgCO2/s	LFMAX	LAI	CANHT m	CANWH m	NIT %	SWFAC	V-STAGE
269	45.78	.00	.000	.0	.000	.000	.00	.00	.00	.00	.00	.00	1.00	.00
270	32.11	.00	.000	.0	.000	.000	.00	.00	.00	.00	.00	.00	1.00	.00
272	24.38	.00	.000	.0	.000	.000	.00	.00	.00	.00	.00	.00	1.00	.00
274	44.60	2070.37	.421	1.1	.561	.897	.02	1.15	.02	.05	.03	3.36	1.00	.16
276	45.59	2117.53	.402	1.5	.762	1.222	.03	1.14	.03	.06	.04	3.36	1.00	.44
278	45.59	2118.67	.400	2.2	1.078	1.707	.04	1.16	.04	.07	.04	3.36	1.00	.73
280	31.51	1465.43	.662	3.8	1.373	2.163	.05	1.10	.07	.08	.05	3.36	1.00	1.03
282	17.64	820.71	.877	6.2	1.480	2.150	.06	.94	.10	.09	.06	3.36	1.00	1.55
284	23.39	1088.70	.805	8.2	2.452	3.827	.10	.99	.15	.09	.08	3.36	1.00	2.07
286	34.49	1606.21	.602	10.7	4.369	6.830	.17	1.10	.22	.11	.10	3.36	1.00	2.64
288	22.20	1034.42	.821	18.1	5.487	6.858	.22	1.02	.34	.12	.12	3.36	1.00	3.18
290	39.84	1857.37	.499	22.4	10.346	12.360	.39	1.16	.49	.14	.16	3.36	1.00	3.72
292	35.28	1645.67	.583	33.7	14.430	15.958	.56	1.10	.73	.16	.19	3.36	1.00	4.27
294	35.68	1664.99	.574	48.1	20.893	21.570	.83	1.12	1.05	.19	.23	3.36	1.00	4.80
296	40.04	1869.42	.489	58.4	28.659	28.541	1.13	1.16	1.32	.21	.26	3.36	1.00	5.28
298	38.25	1786.99	.521	68.5	33.716	33.789	1.35	1.09	1.83	.25	.30	3.36	1.00	5.84
300	36.87	1723.00	.546	79.2	40.707	40.107	1.69	1.10	2.40	.30	.30	3.36	1.00	6.39
302	17.84	834.10	.871	87.0	30.146	29.127	1.39	.99	2.92	.35	.30	3.36	1.00	6.94
304	42.42	1984.22	.435	90.0	52.612	50.768	2.24	1.12	3.44	.41	.30	3.36	1.00	7.50
306	41.82	1957.29	.444	92.1	54.340	51.823	2.35	1.11	3.78	.46	.30	3.36	1.00	7.99
308	37.06	1735.42	.533	94.6	55.775	50.752	2.47	1.13	4.39	.51	.30	3.36	1.00	8.57
310	41.82	1958.98	.439	96.3	59.871	53.236	2.64	1.15	4.89	.58	.30	3.36	1.00	9.13
312	34.88	1634.71	.572	97.3	58.069	50.470	2.62	1.13	5.32	.64	.30	3.36	1.00	9.72
314	37.46	1756.16	.519	97.9	61.124	52.490	2.73	1.13	5.61	.72	.30	3.36	1.00	10.30
316	32.31	1515.16	.618	98.3	57.545	49.764	2.61	1.17	5.79	.80	.30	3.36	1.00	10.92
318	44.79	2101.56	.370	98.3	64.815	55.965	2.80	1.15	5.88	.87	.30	3.36	1.00	11.50
320	39.05	1832.55	.482	98.5	64.161	54.793	2.79	1.16	6.08	.95	.30	3.36	1.00	12.10
322	22.99	1079.44	.794	98.8	48.056	41.571	2.20	1.02	6.00	1.03	.30	3.35	1.00	12.10
324	36.47	1712.77	.529	98.4	62.759	53.898	2.73	1.16	5.74	1.07	.30	3.29	1.00	12.10
326	31.51	1480.52	.625	98.2	58.161	50.387	2.57	1.14	5.45	1.07	.30	3.21	1.00	12.10
328	36.87	1732.44	.517	97.7	61.979	53.959	2.68	1.11	5.17	1.07	.30	3.12	1.00	12.10
330	40.24	1891.30	.448	97.1	62.224	55.192	2.66	1.15	4.88	1.07	.30	3.02	1.00	12.10
332	30.52	1435.15	.641	96.7	54.410	48.259	2.43	1.06	4.59	1.07	.30	2.91	1.00	12.10
334	25.17	1183.81	.748	96.1	46.098	41.808	2.15	1.07	4.30	1.07	.30	2.78	1.00	12.10
336	30.92	1454.45	.631	90.5	44.240	42.642	2.07	1.10	2.36	1.07	.30	2.60	1.00	12.10
338	40.43	1902.35	.437	73.1	30.224	30.212	1.50	1.16	1.28	1.07	.30	2.30	1.00	12.10
340	29.73	1399.03	.653	52.9	10.564	10.544	.83	1.11	.67	1.07	.30	1.79	1.00	12.10
342	33.69	1585.82	.572	34.7	.000	.000	.48	1.15	.37	1.07	.30	1.12	1.00	12.10
343	35.28	1660.56	.539	28.3	.000	.000	.37	1.16	.28	1.07	.30	1.12	1.00	12.10

Appendix G
DEFINITIONS

FILE0 - Crop Specific Coefficients

Table 38. Crop-Specific Coefficients *"Definitions."*

AGRLF	Units of glucose required to produce one unit of leaf tissue.
AGRRT	Units of glucose required to produce one unit of root tissue.
AGRSD2	Units of glucose required to produce one unit of seed when protein is available through mining.
AGRSH	Units of glucose required to produce one unit of shell.
AGRSTM	Units of glucose required to produce *one unit of stem.
ALPHBR	Weight of seed which can be made from one gram of protein, if the protein is used to supply energy and carbon skeletons as well as protein for the seed, g/g.
ATOP	Maximum fraction change in partitioning from top growth to roots if severe water stress occurs.
CNIT1	Y-intercept of the equation which relates the reduction in gross photosynthate (PG) to average canopy nitrogen content.
CNIT2	Linear coefficient of the equation which relates the reduction in gross photosynthate (PG) to average canopy nitrogen content.
CNIT3	Quadratic coefficient of the equation which relates the reduction in gross photosynthate (PG) to average canopy nitrogen content.
CO2BAS	Base line CO_2 concentration in air.
CONGR1	Proportion of the total difference between maximum allowable *leaf mass per unit leaf area (SLW) and current SLW which the canopy can add in one day (0.3).
CONSD1	Y-intercept of the quadratic equation which relates the reduction in the maximum seed and shell growth rates to daily average temperature.
CONSD2	Linear coefficient of the quadratic equation which relates the reduction in the maximum seed and shell growth rates to daily average temperature.
CONSD3	Quadratic coefficient of the equation which relates the reduction in the maximum seed and shell growth rates to daily average temperature.
DEVRT	Relative response of vegetative and reproductive development to temperature.
EFF	Photosynthetic light use efficiency, mol CO_2/mol PAR.
FINREF	Specific leaf area (SLA) of leaves of standard drybean cultivar when plants emerge -- values for other cultivars are calculated in subroutine VARTY, cm^2/g.
FREEZ1	Temperature below which plant is damaged by freezing, leaves are killed, C.
FREEZ2	Temperature below which all growth stops, plants are killed, C.
FRLFF	Fraction of daily increase in vegetative weight which goes to leaves after the day on which the maximum number of V-stages occurs (NDLEAF).

Table 38 Continued. Crop-Specific Coefficients "Definitions."

FRSTMF	Fraction of daily dry weight increase in vegetative plant parts which goes to stems after the day on which the maximum number of V-stages occurs (NDLEAF).
KDIF	Extinction coefficient for diffuse light.
LFANGD	Leaf angle distribution.
LNGSH	Number of physiological days an individual shell grows, physiological days.
NDEVRT	Number of points on temperature response curve for vegetative and reproductive development.
NDVTEM	Number of temperature response curves.
NHWDL	Number of points in the curve for response of canopy height and width to daylength.
NHWPAR	Number of points in the curve for response of canopy height and width to radiation.
NHWTEM	Number of points in the curve for response of canopy height and width to temperature.
NHWTUR	Number of points in the curve for response of canopy height and width to water stress (turgor).
NLITE	Number of entries in table relating light interception to normalized leaf area index (LAI).
NPGSLW	Number of points in the curve for relative reduction of photosynthesis as a function of specific leaf weight.
NPHOTO	Number of points in the curve for relative reduction of photosynthesis as a function of temperature.
NPRIOR	"Reference" stage number for the forthcoming stage.
NSLATM	Number of points in the curve for effect of temperature on specific leaf area.
NSWFAC	Number of paired values in array which describes the effect of the ratio of soil root water supply to transpirative demand, on the relative rate of pegging (pod addition) (PNUTGRO only).
NTYACC	Type of modifiers affecting developmental rate for a given stage during vegetative and reproductive development (physiological time). 1 - Temperature - Vegetative Growth 2 - Temperature - Reproductive Development until Flowering 3 - Photoperiod and Temperature - Reproductive Development until Flowering 4 - Photoperiod and Temperature - R1 - R5 & Temperature R5 - R7 5 - Temperature - Reproductive Development between Flowering and Physiological Maturity 8 - None
NVSHT	Number of points in the curve for canopy height as a function of V-satge.
NVSPT	Number of points in the curve for vegetative partitioning as a function of V-satge.
NVSWH	Number of points in the curve for canopy width as a function of V-stage.
NXFTEM	Number of paired values in array describing temperature effect on partitioning to fruits (XFRUIT).
NXYTEM	Number of points in the curve for temperature effect on pod addition (YTEMPD = f(XTEMPD)).
PARMAX	Value of PAR above which there is no further increase in photosynthesis, moles/m^2.
PCARSD	Fraction of carbohydrate in seed.
PHFAC1	Linear coefficient of equation relating maximum gross photosynthate (PG) per meter square to PAR.

Table 38 Continued. Crop-Specific Coefficients "Definitions."

PHFAC2	Quadratic coefficient of equation relating maximum gross photosynthate (PG) per meter square to photosynthetically active radiation (PAR).
PHPT1	The leaf area index (LAI) at which 63 % of light is intercepted if plants are evenly spaced.
PHPT2	Intercept of equation relating ratio of intrarow spacing to interrow spacing to leaf area index (LAI) required to intercept 63 % of light.
PHTMAX	Maximum amount of CH_2O which can be produced per m^2 if photosynthetically active radiation (PAR) is above the value of PAR above which there is no further increase in photosynthesis (PARMAX) and all other factors are optimal, g/(m^2*day).
PLIGSD	Fraction of lignin in seed.
PLIPSD	Fraction of lipid in seed.
PMINSD	Fraction of minerals in seed.
POASD	Fraction of organic acids in seed.
PORPT	Ratio of petiole to total leaf weight.
PROLFF	Proportion of protein in leaves at the end of the season, after all possible protein has been translocated to seeds.
PROLFI	Proportion of protein in leaves during tissue growth.
PRORTF	Proportion of protein in roots at the end of the season, after all possible protein has been translocated to seeds.
PRORTI	Proportion of protein in roots during tissue growth.
PROSHF	Proportion of protein in shells at the end of the season, after all possible protein has been translocated to seeds.
PROSHI	Proportion of protein in shells during tissue growth.
PROSTF	Proportion of protein in stems at the end of the season, after all possible protein has been translocated to seeds.
PROSTI	Proportion of protein in stems during tissue growth.
R30C2	Grams CH_2O used per gram CH_2O fixed for protein turnover costs in maintenance respiration during 1 hour at 30 °C.
RCH2O	Energy cost to build 1 g of carbohydrate tissue.
REPDVA1	See REPDVA2
REPDVA2	Temperature response curve for reproductive development (V1 to R1) for temperature group IVRTEM 1 or 2.
REPDVB1	See REPDVB2
REPDVB2	Temperature response curve for reproductive development (R1 to R7) for temperature group IVRTEM 1 or 2.
RES30C	Grams CH_2O used per gram top dry weight in maintenance respiration during 1 hour at 30 °C.
RFAC1	Root length per unit root weight, cm/g.
RFLWAB	Relative flower abortion rate.

RLDSM	Minimum root length density in a given layer, below which drought-induced senescence is not allowed, cm/cm^2.
RLIG	Energy cost to build 1 g of lignin in tissue.
RLIP	Energy cost to build 1 g of lipids in tissue.
RMIN	Energy cost to build 1 g of minerals in tissue.
RNH4C	Energy cost to build 1 g of protein in tissue using ammonium as substrate.
RNO3C	Energy cost to build 1 g of protein in tissue using nitrate as substrate.
ROA	Energy cost to build 1 g of organic acids in tissue.
RTDEPI	Depth of roots on day of plant emergence, cm.
RTSDF	Maximum fraction of root length senesced in a given layer per physiological day when water content in a given layer falls below 25 % of extractable soil water, fraction per physiological day.
RTSEN	Fraction of existing root length which can be senesced per physiological day, fraction per physiological day.
RWUEP1	If ratio of total potential daily root water uptake from the soil-plant system (TRWU) to actual transpiration (EP1) reduces below this value, leaf expansion is reduced.
SCV	Scattering coefficient for radiation.
SDPROS	Reference value for protein concentration in calculating SDPRO.
SENDAY	Maximum fraction of existing leaf weight which can be senesced on day N as a function of severe water stress 4 days earlier.
SENMAX	Maximum proportion of total leaf weight as a function of V-stage (XSENMX(I)) which can be senesced due to water stress.
SENPOR	The proportion of leaf weight grown which will have been senesced by a given V-stage (XSTAGE(I)) if no water stress has occurred prior to this V-stage (XSTAGE(I)) -- normal vegetative senescence does not occur if prior water stress has already reduced leaf weight by more than this amount.
SENRT2	Factor by which leaf weight is multiplied to determine senescence each day after physiological maturity (NR7).
SENRTE	Factor by which protein mined from leaves each day is multiplied to determine senescence.
SETMAX	Threshhold for the ratio of supply of CH_2O available for growth of a cohort of podwalls to cohort demand for CH_2O. If this ratio exceeds SETMAX, then seeds are set in all pods of the cohort and none of them are aborted.
SHTHIC	Rate of secondary shell growth (thickening) after the rapid expansion phase (LNGSH) until the pod matures, rate as a fraction of *the maximum growth rate of an individual pod for variety I (SHVAR(I)).
SIZREF	The size of a normal upper node leaf (nodes 8 - 10) of standard cultivar, cm^2/leaf.
SLAMAX	The maximum specific leaf area (SLA) for new leaves when grown under low (nearly zero) radiation but optimum water and temperature for the standard cultivar, cm^2/g.
SLAMIN	The minimum specific leaf area (SLA) for new leaves when grown under infinitely high radiation, optimum water and temperature for the standard cultivar, cm^2/g.
SLAPAR	Effect of radiation on SLA.

Table 38 Continued. Crop-Specific Coefficients "Definitions."

SLAREF	Specific leaf area (SLA) for new leaves during peak vegetative growth for a standard cultivar, cm^2/g.
SRMAX	Relative individual seed growth rate.
STRCON	Coefficient describing the decrease in rate of phenological development as a function of soil water deficit.
THICKN	Rate of secondary leaf thickening.
TURSEN	Constant which describes the exponential shape of shift in partitioning to fruits versus the ratio of soil-root water supply to actual plant transpirative demand. (Not used in BEANGRO).
TURSLA	Effect of water stress on specific leaf area.
TURTHR	Ratio of water supply/transpirative demand at which the maximum increase in partitioning to fruits (XFRMAX) occurs. (Not used in BEANGRO).
VEGDV1	See VEGDV2.
VEGDV2	Temperature response curve for vegetative development for temperature group IVRTEM 1 or 2.
VSSINK	Vegetative stage beyond which sink-limited leaf area expansion can no longer limit photosynthesis or leaf area growth.
WTNEW	Weight of one plant at time of emergence, g.
XFRMAX	Maximum increase in partitioning to fruits induced under water stress, assuming no problem in pod setting, (Not used in BEANGRO).
XHWDL	Daylength coordinates (X-axis) for effect of daylength on canopy height and width.
XHWPAR	Radiation coordinates (X-axis) for effect of radiation on canopy height and width.
XHWTEM	Temperature coordinates (X-axis) for effect of temperature on canopy height and width.
XHWTUR	Water stress coordinates (X-axis) for effect of water stress on canopy height and width.
XLEAF	V-stage at which partitioning to leaves is YLEAF(I).
XPGSLW	Change in photosynthesis as a function of specific leaf weight.
XPHOTO	Temperature at which temperature factor for reducing photosynthesis is YPHOTO(I), °C.
XRTFAC	V-stage at which rate of increase in root depth per physiological day is YRTFAC(I) -- constant rate throughout the season now.
XSENMX	V-stage at which maximum fraction of cumulative leaf growth vulnerable to loss due to water stress is SENMAX(I).
XSLATM	Factors that reduce specific leaf area (SLA) as a function of temperature.
XSTAGE	V-stage by which SENPOR(I) fraction of cumulative leaf growth will have been senesced if no water stress occurred.
XSTEM	V-stage at which partitioning to stems is YSTEM(I).
XSWFAC	Array of values describing the ratio of soil-root water supply to transpirative demand, at which the rate of pod addition is reduced by a given proportion (YSWFAC). (Not used in BEANGRO).

Table 38 Continued. Crop-Specific Coefficients "Definitions."

XTEMPD	Array of temperature values which describes the effect of temperature on the relative rate of pod addition (YTEMPD = 0 TO 1), °C.
XVGROW	V-stage by which maximum leaf area growth per plant since emergence is YVGROW(I).
XVSHT	Effect of V-stage on canopy height.
XVSWH	Effect of V-stage on canopy width.
XXFTEM	Array of temperature values in table lookup describing effect of temperature on partitioning to pods (YXFTEM = 0 TO 1), °C.
YHWDL	Daylength coordinates (Y-axis) for effect of daylength on canopy height and width.
YHWPAR	Radiation coordinates (Y-axis) for effect of radiation on canopy height and width.
YHWTEM	Temperature coordinates (Y-axis) for effect of temperature on canopy height and width.
YHWTUR	Water stress coordinates (Y-axis) for effect of water stress on canopy height and width.
YLEAF	Partitioning fraction to leaves at V-stage XLEAF(I).
YPGSLW	Effect of specific leaf weight on photosynthesis (Y-coordinate of XPGSLW).
YPHOTO	Factor by which photosynthesis is reduced if temperature is XPHOTO(I), between 0 and 1.
YRTFAC	Rate of increase in root depth per degree day at V-stage XRTFAC(I).
YSLATM	Temperatures corresponding to XSLATM.
YSTEM	Partitioning factor for stem growth at V-stage XSTEM(I).
YSWFAC	Array describing the relative (0 to 1) rate of pod addition (pegging) which occurs at a given ratio of soil-root water supply to transpirative demand (XSWFAC). (Not used in BEANGRO).
YTEMPD	The relative rate of pod addition (0 to 1) as temperature (XTEMPD) varies.
YVREF	Maximum leaf area grown per plant by standard cultivar by V-stage XVGROW(I), cm^2/plant.
YVREF	Reference value for maximum leaf area grown per plant by V-stage XVGROW(I), cm^2/plant.
YVSHT	Y-coordinate for canopy height as a function of V-stage.
YVSWH	Y-coordinate for canopy width as a function of V-stage.
YXFTEM	Array describing the relative partitioning to pods (0 to 1 effect on XFRUIT) as temperature increases, °C.

Table 39. Subroutines used in BEANGRO Version 1.01.

CANOPG	Hourly canopy photosynthesis
CANOPY	Computes canopy height and width
CLEAR	Clears screen (video display)
ETRTIO	Stomatal compensation with high CO_2
FRACD	Computes fraction diffuse radiation
FREEZE	Determines damage from freezing
GPHEN	Phenology
GRO	Main calling program of BEANGRO
GROW	Carbon balance rate and state variables
GROWI	Initialize plant variables at V1
HEDGE	Hourly light interception
HRAD	Hourly radiation
HTEMP	Hourly temperature
IDCROP	Selects parameter file
IDWTH	Selects weather file
INPHEN	Initialize varietal traits and phenology
INSOIL	Initialize soil profile
INTRO	Displays introductory panel
INVAR	Select variety parameters
IPCROP	Reads crop parameter file
IPEXP	Select case study experiment & treatment
IPFERT	Select "soil fertility" options PGFAC3
IPFREQ	Select output frequency
IPSENS	Sensitivity analysis
IPSOIL	Select and initialize soil profile
IPTRT	Controls initialization subroutines
IPVAR	Input cultivar description
IPWTH	Input weather on a daily basis
IRRIG	Controls irrigation
JULIAN	Convert calendar day (DD-MM-YY) to julian day
LFCHAR	Traits for single leaf photosynthesis
NAILUJ	Julian day to calendar day
OPECHO	Echo input to screen
OPHARV	Output final harvest data to screen
OPHEAD	Output headers for output files
OPSEAS	Output time series for C, H_2O, N
OPWTH	Generates weather summary output
PHOTIN	Response of light interception to row and plant spacing
PHOTO	Main photosynthesis calling routine
PHOTOD	Integrating loop, diurnal photosynthesis
PHOTOL	Hourly single leaf photosynthesis
PLANT	Controls growth and development subroutines
PODS	Pod and seed C & N accumulation
ROOTS	Depth of rooting
SENES	Senescence as a function of age, N, and water stress
SOLCON	Solar constant
SUNRIS	Time of sunrise & sunset
TABEX	Lookup function for linear interpolations
VEGGR	Vegetative growth and partitioning
VERIFY	Verifies input from keyboard
WATBAL	Water balance - evapotranspiration
WEATHER	Compute hourly weather from daily means
WTHMDI	Sensitivity analysis modifying weather files
WTHMOD	Compute modified temeprature, CO_2, precipitation