ROSESIM: An Interactive Tool for Plant Growth Modeling

Douglas A. Hopper¹

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Summary. One should choose the simplest form of a model as a tool that adequately represents the processes and relationships of interest. ROSESIM was first developed in SLAM II and FORTRAN to run on a mainframe computer, where it had few users and it was cumbersome to learn and use. As use of models on a personal computer (PC) has become more popular for instruction and simulation, ROSESIM was translated first into the American Standard Code for Information Interchange (ASCII) to run in the Beginner's All-purpose Symbolic Instruction Code (BASIC) language in the popular Microsoft Disk Operating System (MS-DOS). As graphical user interface (GUI) Windows applications have gained increased popularity, ROSESIM has been translated into C++ as object-oriented programming (OOP) to run inside Microsoft Windows 3.1. This makes ROSESIM for Windows readily available to virtually every PC user. Features of ROSESIM for Windows are listed and discussed.

Mathematical computer models are used by scientists to represent plant growth and development over a speci-

¹Assistant professor; Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, CO 80523.

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fied range of environmental conditions. Models may be as simple as an equation that relates a single environmental factor with a plant response (Armitage et al., 1981; Berghage and Heins, 1991; Faust and Heins, 1993), or as complex as to relate multiple input factors to plant responses over time (Lieth, 1990; Lieth et al., 1990). Additional complexity combines differential equations into state-variable iterative computer models that accumulate growth response to the state of the plant and the environment, thereby enabling dynamic system simulation (Fishwick, 1995; Holt et al., 1975). As the form of the model increases in complexity, albeit to improve performance, it generally becomes more difficult to use. Choice of the type of simulation model is similar to choice of a tool to perform a task: the simplest yet effective form and interface should be used to make successful predictions and analyses.

The objective was to restructure the ROSESIM plant growth simulation model (Hopper et al., 1994), as developed and verified for accuracy in routines popular on a mainframe computer, into a graphical user interface (GUI) program that would be easily recognizable by a typical computer user/operator and would allow more interactive exchange of information with other current high-end GUI applications. The model also would be easier and more flexible for the average student or grower/manager to implement interaction between the computer model and greenhouse environmental control systems.

Original form of ROSESIM. ROSESIM (Hopper, 1994) was developed initially in the second version of a simulation language for alternative modeling (SLAM II), a language designed for broad modeling capability (Pritsker, 1986). FORMula Translation routines from 1977 (FORTRAN77) were programmed to predict daily plant growth increases by fitting multiple linear regressions (SAS, 1990). SLAM II featured iterative accumulation over simulated time periods from a pinch until predicted flowering using full quadratic equations, and additionally exhibited built-in initialization of variables, iterative accumulations of predictions, automatic time-stepping, sophisticated Runge-Kutta integration (Conte and deBoor, 1980), random process creation, simple graphing, and checks to terminate the simulation upon flowering. The major drawback was lack of portability to other systems, since SLAM II was available only on mainframe computers at limited locations.

First functional personal computer (PC) form of ROSESIM. Availability of higher-performance PCs in the 1990s encouraged the development of a portable version of ROSESIM. The General Written Beginner's All-purpose Symbolic Instruction Code (GW-BASIC) language, as included with the Microsoft Disk Operating System version 4.01 (MS-DOS 4.01) (Microsoft Corp., Redmond, Wash.), exhibited a form for calculations similar to that of FORTRAN77. However, the need to number each line of computer code made

GW-BASIC more cumbersome for developing the iterative program nature. Routines developed in GW-BASIC replaced those originally provided by SLAM II, including initialization, daily iteration, and file input/output. An interactive query/answer system elicited desired input values from the computer user. The user could choose a set of environmental conditions as constant daily input for the whole crop time, or daily environmental conditions that varied daily could be input from a file. This version ran in multiple MS-DOS windows as created by Microsoft Windows 3.1, but lacked the full range of features of a typical Windows application.

Recent GUI version of ROSESIM. Since Windows operates on about 85% of desktop PCs throughout the world (Massey, 1995), and Windows Office alone is currently available on more than 10 million of existing IBM PCs, a great potential exists to run any application on the combined Windows MS-DOS-based platform. Translation to this platform offers the most widespread use for a plant growth model. Programming and adapting ROSESIM for the Windows 3.1 GUI environment required a working knowledge of the C++ language, as well as a specialized Borland C++ package that provided the fundamental windows features with a variety of options (Faison, 1992; Petzold, 1990). Program size and sophistication increased markedly, but so did the convenience of interfacing using default Windows' capabilities. Additional capability was provided by Windows' features, including icon startup, resizable multiple windows, pull-down menus, standard file input and output, option choices from dialog boxes, color choices for window components, window or full screen capture, and simple switching between windows programs. All features available in SLAM II or GW-BASIC versions

ROSESIM Simulation Run
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TNOW	PPF	DT	NT	DWT	DWS	DWL	DWF	SDWT	%FLR
37	265	25.0	16.9	3.9	1.205	1.879	0.887	4.013	0.89
38	199	25.0	17.0	4.1	1.244	1.916	0.984	4.185	0.91
39	271	25.0	16.9	4.4	1.323	1.982	1.140	4.487	0.94
40	214	25.0	17.0	4.6	1.369	2.016	1.264	4.692	0.96
41	169	25.0	16.4	4.8	1.398	2.036	1.358	4.834	0.99
42	277	25.0	16.7	5.1	1.486	2.097	1.549	5.174	1.01

c:\windows\prwin95a.bmp

Fig. 1. ROSESIM for Windows simulation run using input environmental conditions from ASCII data file 'rhhen91a.txt', starting at line 90, which is day of the year 359 (Christmas day). Column TNOW (left side) is the days from pinch or cutback while the simulation ends when column %FLR (right side) reaches 1.0 (or 100% of flowering time accumulated). Variables defined by Hopper et al. (1994).

of ROSESIM were incorporated, and in some cases with greater ease of use or flexibility. C++ object-oriented programming (OOP) allowed similar items, (data, graphs, or labels) and functionality to be inherited (taken directly from already existing routines), thereby reusing common recognizable characteristics and performance. OOP manipulated modular components, setting individual options or characteristics for each one. Programmers and computer users who learn to operate in Windows GUI procedures are able to understand and use new ROSESIM routines.

Features of present version. The following special features are present in ROSESIM for Windows, and many are unique to ROSESIM.

1. Prediction of rose growth and development from pinch (or harvest) until flowering (subsequent harvest).
2. Daily iteration-predicting development; optional daily changes for environmental conditions.
3. Constant average or actual recorded daily environmental conditions input from an external file of the type for ASCII.
4. Choice of International System of Units (SI) or common industry units.
5. Stepping for a select number of days at constant environmental conditions.
6. Output of stem length, fresh weight, and time to flower or dry weight and flower development time (Fig. 1).
7. Coefficients for full quadratic models can be changed at run time to fit various crops.
8. Scaling of growth and development by crop coefficients for specific cultivars.
9. Saving of output to unique file names for later use (i.e., plotting).
10. Simple graphs with multiple trend lines and specific labels may be created and assembled for convenient comparison (Fig. 2).
11. Data in a flexible column format may be input for graphing.

Fig. 2. Multiple graph drawing example from ROSESIM for Windows. Graphs using data sets from different files can be autojoined, numbered, color coded, or labeled appropriately, and then have different symbols of various sizes. Columns of data from any ASCII file may be used as input, and do not necessarily need to be generated by ROSESIM.

Example use for ROSESIM. To illustrate the general functionality of ROSESIM, consider a simple example (Fig. 1). Assume a user has data in a data file named 'rhhen91a.txt' of type ASCII. The data file may contain a multiple line header of written information to explain the file contents, including a line explaining the contents of several columns of data. Several hundred lines, or records, of data may be contained in the file. On each line the contents of separate columns are separated by one or more spaces (considered a free format, since the number of spaces between entries may vary). The user has the flexibility to begin accessing the data at any line in the file, such as at line 90, since it corresponds to day of the year 359 (Christmas). Culturally, roses may be pinched on this day to time flowering for Valentine's Day, which is the most popular holiday for cut rose sales. ROSESIM assumes the file contains at least three columns of data representing photosynthetic photon flux (PPF), day temperature (DT), and night temperature (NT). The user stipulates in what order the columns appear (i.e., of a total of 14 columns in the file, the values for PPF, DT, and NT appear in columns 7, 3, and 11, respectively). ROSESIM reads in the stipulated data a line at a time, assuming each line represents a day of growth, and ROSESIM displays to the screen predicted accumulated growth for each day, as well as predicting how far the

flower has developed as a percentage of total time to flower. When the percentage becomes greater than 100%, flowering is assumed to occur, and the simulation terminates. A user may choose to display output of either fresh weight or dry weight predictions. Whatever is displayed on the screen as a completed simulation can be saved to a file of type ASCII for further plotting or statistical analysis. If a user selects the dry weight option, then the following values are displayed (and can be saved): day of the simulation (TNOW), PPF, DT, NT, total dry weight (DWT), stem dry weight (DWS), leaf dry weight (DWL), flower dry weight (DWF), summed total dry weight (SDWT), and the percentage of development toward flowering (%FLR) (Fig. 1). The user may elect to run an entire simulation from pinch to flowering, or the user may step through the development one or several days at a time, observing trends in the data with each step. The user may choose to stop reading data from the file, and instead supply expected PPF, DT, and NT values for a step of time, and thereby obtain prediction of response to possible environmental conditions which one might expect to observe in a particular season of the year. Comparison of several such simulations would allow a grower/manager to compare several control strategies, or would allow a student to learn the relative importance of various level of PPF, DT, and NT on growth responses.

User's guide. A user's guide for ROSESIM for Windows has been developed for the novice and advanced computer user. The guide explains installation of an icon onto Windows Program Manager and how to run ROSESIM from the Windows File Manager. General features of ROSESIM are explained with text and graphics. Current on-line help is limited; however, users having experience with Windows would be comfortable using the program. Special considerations also are covered, as are tips for efficient use. The user's guide is designed to introduce a new user to the most commonly used features, many of which have been listed above.

Uses for present version. ROSESIM was designed with default model equations to predict daily rose growth increments in response to set ranges of PPF, DT, and NT (Hopper et al., 1994). Coefficients for equations representing other crops may be read in at run time from associated files. Day-to-day scenarios can be input to the model to predict plant response. Since output is in generalized ASCII format, data may be read into sophisticated graphing packages (e.g., DrawPerfect, WordPerfect Corp., Orem, Utah; Powerpoint, Microsoft Corp, Redmond, Wash.; Quattro Pro, Borland Corp., Scotts Valley, Calif.; SAS, Cary, NC; SigmaPlot, SigmaPlot Corp, Corte Madera, Calif.), or simple graphing routines built into ROSESIM may be used to make quick comparisons of results (Fig. 2). Comparisons in realtime may read in daily output of environmental conditions from a greenhouse environmental control computer (Priva Computers, Vineland, Ont., Canada; Wadsworth Control Systems, Denver, Colo.), and resulting growth predictions can be used by a commercial grower or researcher to alter set points and subsequent growth. Generally, setpoints are chosen by an experienced grower/manager based on recommendations to produce desired crop performance (Fisher et al., 1993). Graphing various anticipated scenarios also can aid in the decision-making process. ROSESIM for Windows presents tabular and graphical information to aid rose growers in making such decisions.

In summary, ROSESIM for Windows is a user-friendly tool for the prediction of plant growth response to known or anticipated environments.

Predicted responses may be compared to enable red-time control, or values may be saved for later scientific analysis.

Resources available. A copy of the program and user's guide may be obtained from D.A.H. via mail for a nominal fee to cover cost of shipping and handling, and the author maintains a copy on the Colorado State Univ. mainframe computer for access by the common file transfer procedure (ftp) via the Internet. Contact D.A.H. for further information.

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