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User's Guide for SeedCalc: A Decision-Support System for Integrated Pest Management in Slash Pine Seed Orchards

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Abstract

SeedCalc, a decision-support system designed for use on personal computers, evaluates the consequences of different pest management strategies in slash pine (*Pinus elliottii* Engelm. var. *elliottii*) seed orchards. This interactive program allows managers to enter orchard survey data and manipulate pesticides applied, application equipment costs, insect damage rates, strobilus development rates and beginning populations, and pesticide efficacy rates to develop a pest management program that best fits their needs. This guide provides user instructions for SeedCalc, presents screen and printer examples, and describes the structure, assumptions, default values, and flow charts of the system.

Keywords: Cone and seed insects, decision-support system, model, *Pinus elliottii*, slash pine.

Introduction

Numerous studies have been conducted since the late 1950s on the management of southern pine seed orchards (Barcia and Merkel 1972; Yates and DeBarr 1984). These studies have generated considerable information on seed orchard pests, pest management, orchard productivity, and orchard responsiveness to other management practices. Useful for designing pest management strategies in southern pine seed orchards, this information is difficult to integrate into a manageable system.

Managers of southern pine seed orchards have been unable to quickly predict and easily interpret the outcomes of different pest management programs. The consequences of modifying pest management programs usually remain unknown until the efficacy of the modification can be measured when cones reach maturity, generally in 2 years. Integrating pest management alternatives with other orchard management practices further complicates the prediction and interpretation process.

SeedCalc is a decision-support system for integrated pest management[1] (IPM) in slash pine (*Pinus elliottii* Engelm. var. *elliottii*) seed orchards. A decision-support system is an interactive computer-based system designed to help decision makers use data, narrative information, and models to solve unstructured problems (Coulson and Saunders 1987). With SeedCalc managers can rapidly predict and interpret the consequences of using different IPM strategies on individual sites. SeedCalc also facilitates the rapid utilization of on-site survey data for predicting seed yields. Survey data collected from sampling methods that estimate cone and seed production and pest damage rates (Bramlett and Godbee 1982; Fatzinger and others 1988, 1990) are especially appropriate for customizing this system to a seed orchard.

SeedCalc uses several independent modules (models) to simulate cone and seed production, pest damage, and pesticidal control. A model is an abstraction or

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[1] Integrated pest management is the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable (Waters 1974).

representation of a system process (Starfield and Blecoch 1986), i.e., a simplification of reality (Worner 1991). SeedCalc was developed using methods similar to those described by Forrester (1968). Simple rate equations are used in SeedCalc to describe intermediate changes in the population densities and conditions of strobili and seed within an orchard over short periods of time. These changes and the effects of pest damage, pesticide efficacy, and other perturbations are accumulated throughout the development of the strobili. Managers can use the models to estimate gains and losses likely to result from specific pest management strategies.

User-installation, simple configuration procedures, and menu-driven operations facilitate the use of SeedCalc on a desk top or portable personal computer. Information and reports can be viewed on the screen or printed. And the system includes other important features:

- A tutorial illustrating the major features of SeedCalc. The tutorial's on-screen prompts allow the user to move through the screens at leisure.

- Several on-line help screens and messages to assist the user. Errors in the format or type of data entered by the user are recognized, and the user is prompted to re-enter the data in the correct format.

- Ability to simulate two pest management plans with each run of the system. This feature facilitates evaluating and comparing different pest management and orchard management strategies. A final report comparing cone and seed yields is available.

- Program default values to simulate factors affecting seed orchard productivity (pest damage rates, strobilus productivity, pest management technologies). Managers can customize these default values to better describe their own orchards.

Arrangement of the User's Guide

We arranged the User's Guide for SeedCalc to facilitate the following activities:

1. Installing the program from one high-density diskette (5¼" or 3½") onto a hard drive,
2. Understanding the general operations of SeedCalc (flowchart provided),
3. Starting up quickly,
4. Running a tutorial version of SeedCalc,
5. Reading step-by-step instructions for running SeedCalc,
6. Previewing most screen displays,
7. Reviewing the functions of the modules comprising the SeedCalc, and
8. Referencing pertinent literature cited.

Getting Started

Hardware and Software Requirements

SeedCalc is made up of 58 files totaling nearly 1.2 megabytes of program coding. SeedCalc runs on personal computers equipped with MS-DOS version 3.0 (or later). SeedCalc is programmed in Quick Basic ™ to optimize program execution. Although the system will run with older microprocessors (e.g., 8088), faster processors (386, 486, or equivalent) will considerably reduce the time needed to execute a pest management plan. The software will work on both monochrome monitors with text-based graphics cards and color monitors with higher resolution graphics. SeedCalc produces hard copy on dot matrix and laser printers. The output is formatted for an 80-column width, 8.5- by 11-inch paper portrait mode.

Installing SeedCalc

We strongly encourage copying SeedCalc to a hard drive because hard drives access stored files much faster than floppy drives. To copy files to your hard drive, you must first create the subdirectory "SEEDCALC" on your hard drive (drive C:) as follows:

- Move to your root directory — type CD\
- Make a subdirectory called SeedCalc — type MD SeedCalc
- Move to the subdirectory SeedCalc — type CD\SeedCalc

Copy the files from the program disk(s) to your hard drive. Place disk in drive A (assumes hard drive is drive C):

- Copy disk files to your hard drive — type COPY A:*.* C:

The GRAPHICS procedure correctly (automatically or manually) sets the graphics display:

- Set the system graphics — type GRAPHICS

Although you only need to follow this procedure once, you must repeat it anytime you wish to reset the program's graphics display, e.g., if you add new hardware to your computer.

Overview of SeedCalc

SeedCalc has 18 program modules. Fourteen are system modules that interact to simulate seed production, pest damage, and pest management in slash pine seed orchards. The remaining four modules are used to modify the system's default values. The program integrates data entered by the user and consists of more than 278 variables, 117 data arrays, and 37 data files and associated batch, document, and text files.

The operational sequence for SeedCalc is illustrated in figure 1. Initial menus access the interactive programs, a tutorial, and a variety of other information. SeedCalc simulates two pest management plans (Plans A and B), so comparing plans is possible. The first step in creating management plans is to enter information about the size of an orchard and its flower crop. Options are available in SeedCalc to modify pest damage rates, pesticide application procedures, and orchard parameters for each of the two pest management plans. Entered separately for each plan, the modifications are stored separately. When modifications are completed, the program will simulate the results of each plan. SeedCalc will also provide a comparative economic analysis of the results. The user must complete input, analysis, and printing in one session because all modified values and inputs are not automatically saved when exiting SeedCalc. The interactions between the 14 system modules are illustrated in figure 2.

Start-Up Procedure

Start SeedCalc by moving to the SEEDCALC subdirectory on your hard drive (created in install procedures), then type SEEDCALC at the DOS prompt. Using the following procedure, you can create a batch file to automate this procedure:

• Move to your root directory	type CD\
• Create the batch file ORCHARD.BAT	type COPY CON SEEDCALC.BAT type C: type CD\SEEDCALC type SEEDCALC press the F6 key

Now, when you type SEEDCALC, the batch file will move to the proper subdirectory on your hard drive and start SeedCalc.

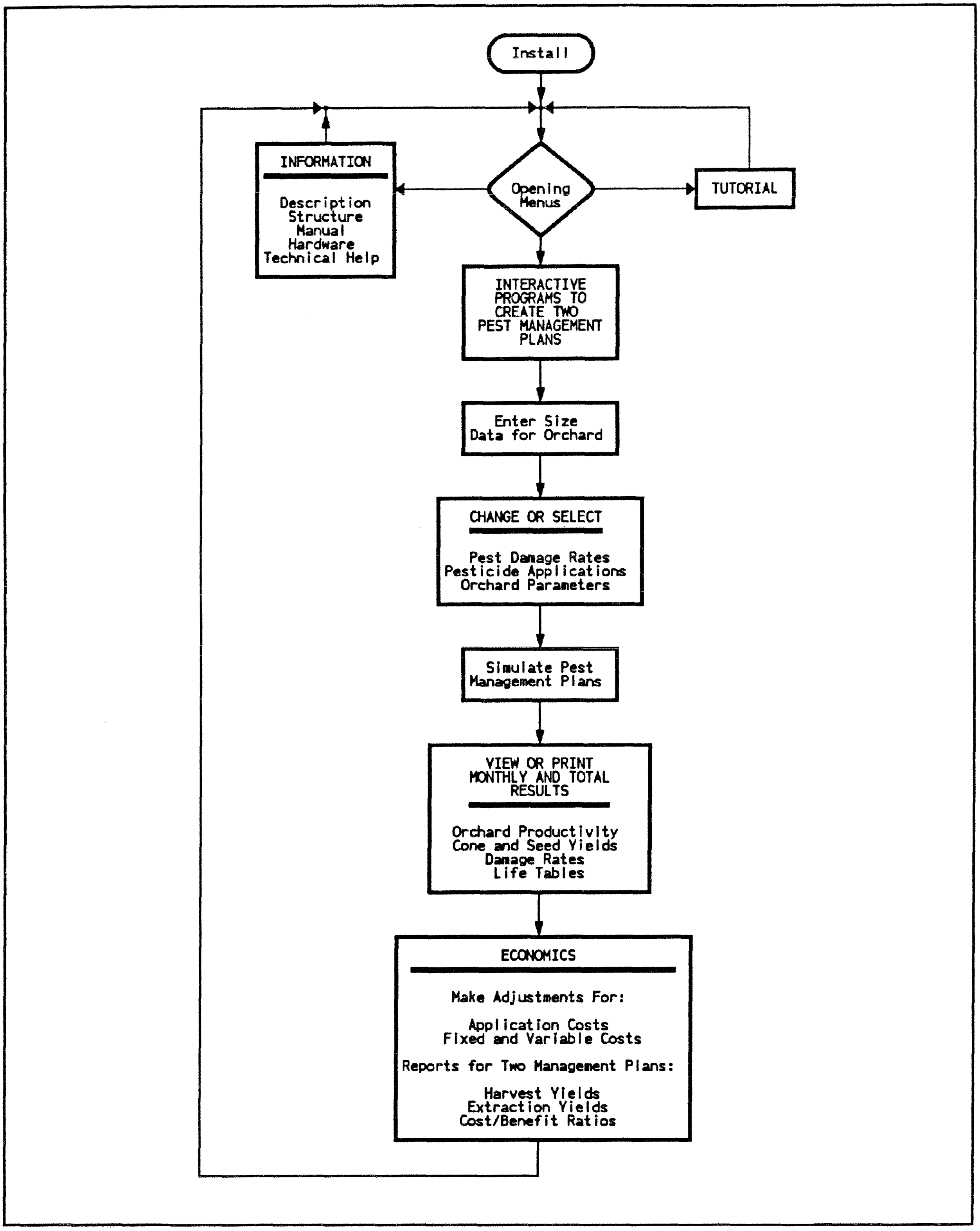


Figure 1—Operational sequence for interactive programs. Opening menus give access to a tutorial and other information on SeedCalc. The system allows for comparisons by simulating two pest management plans.

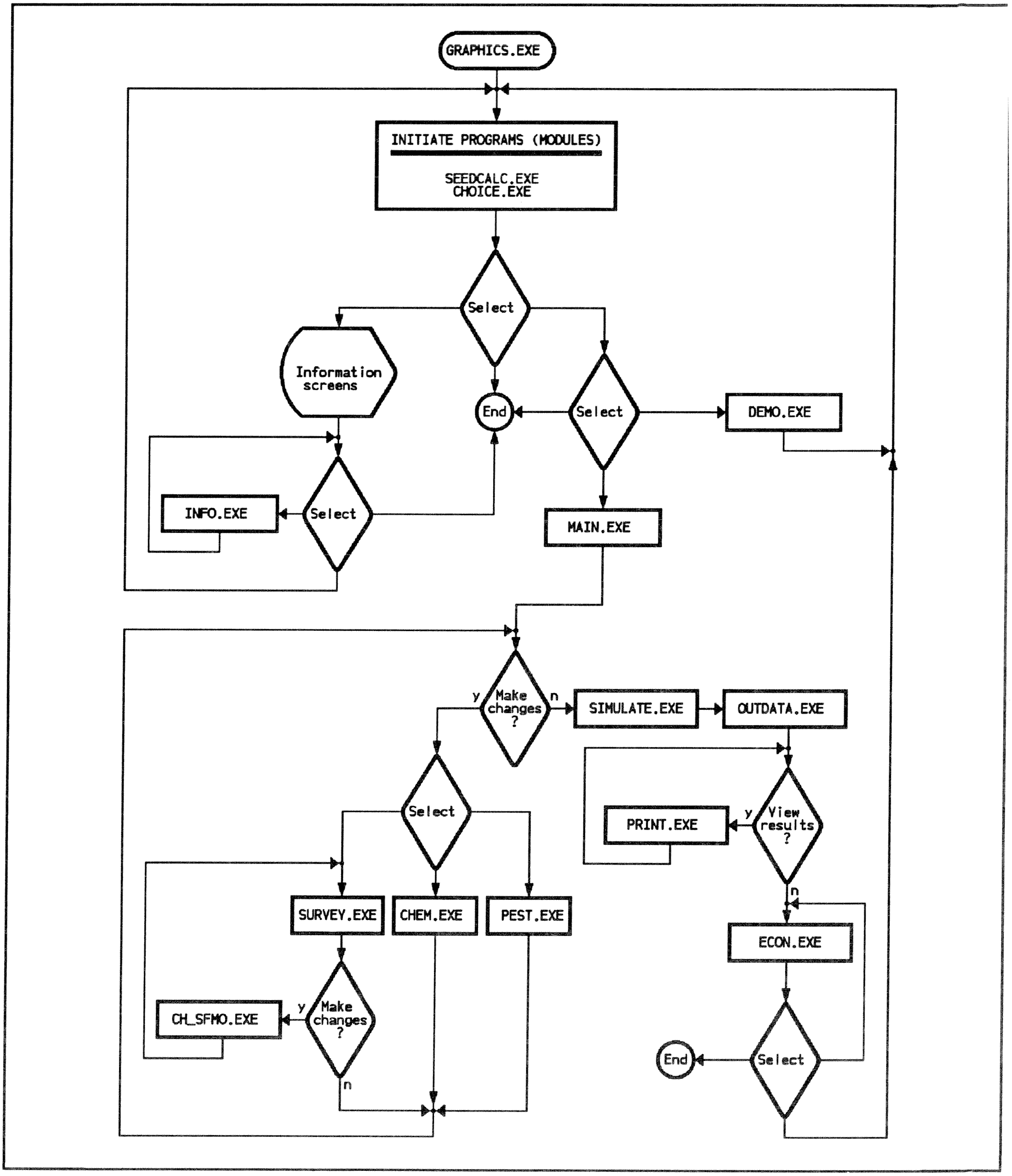


Figure 2—Interactions between the 14 system modules of SeedCalc. The filenames for modules end with a ".EXE" suffix. The function of each module is described under the section, "How SeedCalc Works."

The title screen to SeedCalc will appear and give you three options: (1) start the simulation, (2) obtain program information, or (3) exit back to DOS.

```
SeedCalc: A Decision-Support System for IPM

        in Slash Pine Seed Orchards

   USDA Forest Service & Florida DACS

          Version No. 1.0  1995

*****************************************************
NOTE: Make sure your 'CAPS LOCK' key is turned ON
*****************************************************

          Enter 1   Start Simulation
                2   Information
                3   Exit
                    [__]
```

The option to start the simulation is described in the next section. The Information option will display information about program structure, contacting authors, and hardware/software requirements. You may also print a short disk-based version of the manual when you select this option.

Exiting SeedCalc

The preferred method for leaving the program is to use various exit points provided in the SeedCalc menus. If absolutely necessary, you can also exit SeedCalc by pressing the Control and Break keys simultaneously, then the Return key.

Creating Management Plans

Individual menus in SeedCalc are identified by a code number in the upper left corner. We provide two options, which appear on many of SeedCalc's menus, to facilitate creating management plans:

- "Accept Current Values" uses the current values (system defaults or user modifications) and continues program execution.

- "Cancel, Return to Previous Menu" cancels recent modifications in the current module (such as pest damage or pesticide application modules), restores default values, and returns to either the previous or a specified menu.

Entering Orchard Data

The first menu (I {M1}) will prompt you to enter information concerning the size of the orchard.

```
I {M1}

              ____________________________________________

                          Enter the following:
              ____________________________________________

                  1)  [________]  Initial number of female strobili
                                   (flowers)/acre

                  2)  [________]  Orchard size (total acres)

                                          or

                           Enter R to Return to Initial Menu

               ____________________________________________
               Note:  [___] is used throughout the system
                             to indicate user input
```

We suggest you enter any reasonable estimates of initial numbers of flowers and orchard size for the first few work sessions. This will allow you to acquire a better sense of SeedCalc's capabilities. In later sessions, however, you may wish to enter data for specific orchards or clones collected. We recommend using survey techniques, such as the Inventory Monitoring System (IMS) of Bramlett and Godbee (1982) or the Survey and Pest Monitoring System (SPMS) of Fatzinger and others (1990). Although data can be estimated from other records or surveys of orchard productivity, the IMS and the SPMS control for differences in clonal variation.

Modifying SeedCalc's Default Values

Two pest management plans (Plans A and B) can be created by making two sets of modifications to SeedCalc's default values. Such modifications consist of different adjustments to default values of pest damage rates, pesticide applications, and cone and seed factors (orchard parameters). The categories of modification that can be included in a plan are selected from menu I {M2}.

```
I {M2}

          ________________________________________
                                              ENTER
          Modify Current Values               _____

              Pest Damage Rates                 1
              Pesticide Applications            2
              Orchard Parameters                3

          Cancel, Return to Previous Menu       R

          Accept Current Values                 A
          ________________________________________
                                              [_1_]
```

Program execution will continue, and new menus will facilitate modifications of the default values. The program will return to menu I {M2} after modifications are completed for the selected category.

Adjusting Pest Damage Rates

Default values in SeedCalc simulate pest damage and other losses of female strobili and seeds in the absence of pest management. You can modify the default values to more accurately reflect the conditions in a given orchard by selecting "Pest Damage Rates" (choice 1 on menu I {M2}). The program will then proceed to menu I {P1}. SeedCalc's original default values for pest damage can be modified either temporarily during the current work session or permanently to customize the default values for a specific orchard.

Monthly or Global Modifications

The default values for damage to female strobili can be modified on either a monthly or global (23-month total) basis by entering "1" or "2" at menu I {P1}. Zeros (= no pest damage) can be entered for all months by pest category only when the "Total rate per pest" (option 2) is selected. When zeros are entered for all months under the "Monthly rate per pest" (option 1), the program uses SeedCalc's default values for pest damage.

```
I {P1}

              PEST DAMAGE RATES                   ENTER

              Modify Current Values

                Monthly rate per pest
                  (months 1 to 23)                  1

                Total rate per pest
                  (23-month sum)                    2

              Cancel, Return to Previous Menu       R

              Accept Current Values                 A

              View or Print Pest Damage Rates       V or P

                                                  [__]

Note: All monthly rates for individual pest categories can be set
      to zero (= no pest damage) only under option 2 (total rate).
```

The option "View or Print Pest Damage Rates" produces tables of current values for rates of strobilus attack or strobilus mortality. Before displaying the tables, a menu will request selection of the type of damage you wish to view.

```
I {P1a}

              Select type of damage you want to view:

                   % Mortality          M
                   % Attack             A

                                       [_M_]
```

You decide which management plan (A or B) will reflect changes in strobilus damage in the next menu I {P2}.

```
   I {P2}

            PEST DAMAGE RATES                      ENTER

            Select Management Plan and
              Type of Change

                Plan A:  Temporary changes           1
                         Permanent changes           2

                Plan B:  Temporary changes           3

            Cancel, Return to Previous Menu          R

            Accept Current Values                    A

                                                   [___]
 Temporary = changes apply to this simulation run only
 Permanent = changes Plan A (this run) and Plans A and B (future runs)
```

Options "1" or "3" temporarily change the default values for each plan. These temporary changes can be restored to the default values by selecting the "Cancel, Return to Previous Menu" option. Option "2" changes the default values for Plan A for this simulation run; subsequent simulation runs will use these Plan A default values for both Plans A and B. After using Option "2," however, SeedCalc's original default values can only be restored by returning to the DOS prompt and typing "RENUPEST." After an option is selected, the program will proceed to menu I {P3}.

```
I {P3}

        PEST DAMAGE RATES
        PLAN A (temporary changes)              ENTER   MODIFIED

         Select Pest Category to Modify

            Slash pine flower thrips              1
            Coneworms                             2
            Unidentified insects                  3
            Unknown                               4

          Accept Current Values                   A

          Cancel, Return to Previous Menu         R

                                                [_1_]
```

Selecting Pest Categories

You can modify up to four categories of pests that damage strobili: (1) slash pine flower thrips, *Gnophothrips fuscus* (Morgan); (2) coneworms, *Dioryctria* spp.; (3) unidentified insects (including the pales weevil, *Hylobius pales* (Herbst), May beetle, *Phyllophaga micans* (Knoch), and sawyers, *Monochamus* spp.); and (4) unknown factors including adverse weather conditions, an inadequate supply of pollen (Sarvas 1962), and nymphal feeding by the seed bug *Leptoglossus corculus* (Say) (DeBarr and Ebel 1974). When a category is selected, the program will proceed to either menu I {P4} for changing monthly rates or menu I {P5} for changing global rates of pest damage.

Changing Monthly Rates

Estimates of pest damage are entered in the following sequence for the selected category in menu I {P4}: (1) month number (assuming months are numbered from 1 to 12 beginning with January), (2) percent attack, and (3) percent mortality. Up to 23 monthly estimates can be entered for each category to simulate damage to strobili over a 2-year period. When only zeros are entered for damage by a pest category under the monthly rates, SeedCalc ignores the zero entries and uses program default values. Zero values for one or more pest categories can be entered only by selecting "Total rate per pest" (option 2) from menu I {P1}. New distributions of attack and mortality are calculated by SeedCalc using the monthly data entered for the pest category selected. Default values for other pest categories remain unchanged until the category is specifically selected for change.

The following example shows how screen I {P4} would appear when pest category 2 (coneworms) is selected for modification. May (month 5) monthly values are 25 percent attack and 20 percent mortality, and June (month 6) values are 5 percent attack and 3 percent mortality.

```
I {P4}

MODIFY CURRENT VALUES                                    >>>---> WHEN FINISHED,
PEST DAMAGE RATES                                                enter an  A
PLAN A (temporary changes)  Coneworms                            for Month No.

Month No.    % Attack    % Mortality  |  Month No.    % Attack    % Mortality

 [__5__]     [_25__]     [_20__]
 [__6__]     [__5__]     [__3__]
 [__A__]

Note:  % Attack should be greater than or equal to % mortality
       Enter percentages as follows: 5.7 for 5.7%
```

Changing Global Rates

Estimates for the total rates of strobilus attack and mortality over a 23-month period can be entered for each of the four damage categories in menu I {P5}. The program distributes these rates over the 23-month period of strobilus development. New distributions are calculated to parallel the corresponding default distributions of attack and mortality rates for each category. Thus, the default distributions are used to define the shape of the new distributions, but the new distributions reflect the modified damage rates as entered for each pest category selected.

The following example shows how screen I {P5} will appear when pest category 2 (coneworms) is selected for modification, and global values of 25 percent attack and 20 percent mortality are entered.

```
I {P5}

          MODIFY CURRENT VALUES
          PEST DAMAGE RATES
          PLAN A (temporary changes) Coneworms

          Enter total % damage attributable to Coneworms
          over a 23-month period of development:

               % Attack  [_25__]    % Mortality  [_20__]


Note—% Attack should be greater than or equal to % mortality
     Enter percentages as follows:  5.7 for 5.7%
```

The program will return to menu I {P3} after entries in menus I {P4} or I {P5} are made. An asterisk will appear in the column labeled "Modified" to indicate which pest categories have been altered. Additional categories of pests can then be chosen for modification from menu I {P3}.

Applying Pesticides

You can simulate the effects of applying pesticides and using specific pesticide application techniques for each management plan by selecting the Pesticide Applications option of menu I {M2}. Selecting a pesticide spray schedule for only one of the two pest management plans will allow you to compare a management plan using pesticides to a plan not using pesticides.

Each plan is simulated individually and is identified as either Plan A or Plan B by selecting "1" or "2" from menu I {C1}.

```
I {C1}

SPRAY ORCHARD
ESTABLISH SPRAY APPLICATIONS          ENTER

    Apply spray to Plan A               1
    Apply spray to Plan B               2

Cancel, Return to Previous Menu         C

Accept Current Values                   A

                                       [__]
```

Application Methods

After selecting the plan, you can choose the method of pesticide application on the next menu display (I {C2}). The method selected will reflect differences in the costs and efficacy of application by fixed-wing aircraft, rotary-wing aircraft, air-blast sprayers, mist blowers, or hydraulic sprayers.

```
I {C2}

CHOOSE OPTION                          ENTER

Aerial Application by:

     Fixed-wing aircraft                1
     Rotary-wing aircraft               2

Ground Application by:

     Air blast or mist blower           3
     Hydraulic sprayer                  4

Cancel, Return to Previous Menu         C

                                       [__]
```

Spray Schedules

You can select a spray schedule from one of SeedCalc's four default schedules or you can design a custom schedule. Default spray schedules can be modified by deleting individual spray applications. The spray schedule selected will determine the efficacy of pesticide applications simulated over a 2-year period. Four conventional spray schedules using up to two of the following insecticides serve as defaults: acephate, malathion, azinphosmethyl, *Bacillus thuringiensis* Berliner, or fenvalerate. Estimates of the efficacy of each application are supplied. In SeedCalc, only one pesticide application can be made per month. SeedCalc uses monthly average values for the efficacy of pesticides taken from the literature and unpublished sources. The day of the month is not considered in SeedCalc because local weather conditions, pest and plant phenology, and other factors will affect the specific date of application. The option "custom spray schedule" allows you to specify monthly use of different pesticides throughout the 23-month period of strobilus development. When custom spray schedules are designed, the program will attempt to apply default estimates for the efficacy of each proposed pesticide application. If default values are not available for a proposed pesticide application, SeedCalc will request that you enter estimates for the efficacy of the proposed application.

The use of either a conventional spray schedule or a custom spray schedule is selected from the next menu (I {C3}).

```
I {C3}

        CHOOSE OPTION
        SPRAY ORCHARD
        ESTABLISH PESTICIDES FOR PLAN A        ENTER

            Use a conventional schedule          1

            Custom spray schedule                3

            Cancel, Return to Previous Menu      C

                                               [__]
```

Conventional Spray Schedule

Selecting the option to "Use a conventional spray schedule" from Menu I {C3} will produce menu I {C4}.

```
I {C4}

        SPRAY ORCHARD
        USE A CONVENTIONAL SCHEDULE FOR PLAN A     ENTER

        Select one of the pesticide spray schedules:

              Acephate                              1
              Azinphosmethyl                        2
              Bacillus thuringiensis                3
              Fenvalerate                           4

        Cancel, Return to Previous Menu             C

                                                  [__]
```

After you select a pesticide, a conventional spray schedule for that pesticide in slash pine seed orchards will be listed in menu I {C5}.

```
I {C5}

        SPRAY ORCHARD
        THE CONVENTIONAL SCHEDULE FOR PLAN A

        (The same schedule is applied for 2 years)

                January          Malathion
                February         Malathion
                March
                April            Azinphosmethyl
                May              Azinphosmethyl
                June             Azinphosmethyl
                July             Azinphosmethyl
                August           Azinphosmethyl

        Do you want to accept this conventional schedule?  Y/N

                          [__]
```

If you accept the conventional schedule, enter "Y" in menu I {C5}, and the program will return to menu I {C1}. If you do not accept the conventional schedule, enter "N," and the program will proceed to modified menu I {C3}.

```
I {C3}

        CHOOSE OPTION
        SPRAY ORCHARD
        ESTABLISH PESTICIDES FOR PLAN A       ENTER

            Use a conventional schedule         1

              Delete spray(s) from a
              conventional schedule             2

            Cancel, Return to Previous Menu     C

                                              [__]
```

You can return to menu I {C4} to select a different conventional schedule by entering "1," or you can customize by deleting individual applications of the conventional schedule by selecting "2" and proceeding to menu I {C6}.

```
I {C6}
CHOOSE OPTION
SPRAY ORCHARD
DELETE SPRAYS FROM CONVENTIONAL SCHEDULE
```

No.	Month	Spray	No.	Month	Spray
1	January	Malathion	13	January	Malathion
2	February	Malathion	14	February	Malathion
4	April	Azinphosmethyl	16	April	Azinphosmethyl
5	May	Azinphosmethyl	17	May	Azinphosmethyl
6	June	Azinphosmethyl	18	June	Azinphosmethyl
7	July	Azinphosmethyl	19	July	Azinphosmethyl
8	August	Azinphosmethyl	20	August	Azinphosmethyl

```
WARNING screen for first time users          W
Select month number(s) to delete sprays      No.
When finished modifying values               A
Cancel, Return to Previous Menu              C     [__]
```

Selecting the "WARNING" screen presents the following message:

```
The effects of deleting sprays are unknown.
They are simulated for cones but not for
seed quality.  The effects on seed quality
can be entered later in the program—if
not, their effects are deactivated.

        (Press Spacebar to Continue)
```

When applications of pesticides are deleted for selected months, the numbers designating those months (month numbers) will be displayed in the lower half of the menu. When you finish modifying (deleting month spray applications) the conventional spray schedule, enter "A" to select the option "When finished modifying values" to proceed to menu I {C10}.

```
I {C10}
CHOOSE OPTION
SPRAY ORCHARD
________________________________________________________________

   Enter the Expected Values for Percent Reductions in Seed Damage
              for each of the following factors:
________________________________________________________________

                Empty seed                        1
                Seed bug damaged seed             2
                Seedworm damaged seed             3
                Seed damaged by unknown factors   4

                % Change in number of seed/cone   5

                Accept Current Values             A

        ENTER CODE  [__]    ENTER % REDUCTION EXPECTED  [__]
```

You can enter expected values for seed damage resulting from different factors in menu I {C10}. The code for a factor (1 through 4) is entered and followed by an estimate of the percent reduction in seed yield associated with that factor. The values entered are displayed in a third column of menu I {C10}. SeedCalc will substitute default values for those left unmodified. When you have completed all changes, enter "A" to select option "Accept Current Values" and return to menu I {C1}.

Custom Spray Schedule

When you select the "Custom spray schedule" option from menu I {C3}, the program will proceed to menu I {C7}. You can design a custom spray schedule by selecting pairs of code numbers to represent a month and a pesticide for each application in the schedule.

```
I {C7}

CHOOSE OPTION                              >>>---> When finished designing a
SPRAY ORCHARD                                      schedule, enter an  A  for
DESIGN A SPRAY SCHEDULE                            month number.
-------------------------------------------------------------------------------
  FIRST YEAR        SECOND YEAR       PESTICIDE        SCHEDULE SELECTED

 1.  January        13.  January      1.  Acephate          1  Malathion
 2.  February       14.  February     2.  Azinphosmethyl    2  Malathion
 3.  March          15.  March        3.  B. thuringiensis  5  Azinphosmethyl
 4.  April          16.  April        4.  Fenvalerate
 5.  May            17.  May          5.  Malathion
 6.  June           18.  June
 7.  July           19.  July
 8.  August         20.  August
 9.  September      21.  September
10.  October        22.  October
11.  November       23.  November
12.  December

                  Month [___]   Pesticide [__]
           Enter a  C  to Cancel, Return to Previous Menu
```

The selections (month numbers and pesticides) for the custom spray schedule will be displayed under the column "SCHEDULE SELECTED" as you enter them. When you complete the schedule, enter the letter "A" in the brackets for Month. The program will then proceed to menu I {C8}, display the custom spray schedule, and provide an opportunity to change the schedule.

```
I {C8}

CHOOSE OPTION
SPRAY ORCHARD
DESIGN A SPRAY SCHEDULE
__________________________________________________________________

   1   January     Malathion
   2   February    Malathion


   5   May         Azinphosmethyl

__________________________________________________________________
            Do you want to make any changes? [__]   Y/N
                 Y = change, add, or delete sprays
                 N = continue (go to next menu)
```

You can enter "Y" to change or delete any of the individual sprays included in a custom design or to add individual sprays to the schedule. The lower portion of the menu (beneath the line) will change according to the options you select. All changes are displayed in the upper portion of the menu as you make them. The different lower portions of menu I {C8} follow.

```
__________________________________________________________________
            Do you want to make any changes? [__]   Y/N
                 Y = change, add, or delete sprays
                 N = continue (go to next menu)
```

If "Y" is selected, the lower portion of the menu will change.

```
__________________________________________________________________
 Change Record  R     Delete record  D
 Add Record     A     Cancel         C    [__]
```

If "R" is selected to "Change Record," the lower portion of the menu changes, requesting month number and pesticide choice.

```
Enter month number and different pesticide choice
Month  [___]    Pesticide code number  [__]
```

If "A" is selected to "Add Record," the lower portion of the menu will ask you to pair an additional month (number) and pesticide.

```
Enter month number and additional pesticide choice
Month  [___]   Pesticide code number  [__]
```

If a "D" is selected to "Delete Record," the lower portion of the menu will change and you can enter the month (number) to delete.

```
Enter month number for which application is to be deleted
Month  [___]
```

When each entry is completed, the lower portion of the menu reverts to the original I {C8} format.

```
Do you want to make any changes?  [__]   Y/N
     Y = change, add, or delete sprays
     N = continue (go to next menu)
```

When all changes have been made, you can select "N" and continue to the next menu.

If your changes include spray applications with no default values for the efficacy of a pesticide, the program will proceed to menu I {C9}. This menu will prompt you to enter estimates of the expected percentage reductions in attack rates of different pests during specific months. Menu I {C9} is repeated for each instance where changes in spray schedules are not supported by default values.

```
I {C9}

CHOOSE OPTION
SPRAY ORCHARD
DESIGN A SPRAY SCHEDULE
________________________________________________________________

        Empirical data for the efficacy of the following
        application is not currently available:

              Month 1        Spray = Azinphosmethyl
        ______________________________________________

             Enter estimated % reduction (0 to 100)
             in attack rates during month 1 due to
             an application of Azinphosmethyl for:

                  Slash Pine Flower Thrips  [____]
________________________________________________________________
   Note:  Zero data can be entered by simply pressing the ENTER key
```

SeedCalc also presents Menu I {C10} as a follow-up to menu I {C9}. Expected values are requested for percent reductions in seed damage corresponding to custom spray schedules when published empirical data is unavailable. As each code and percentage combination is entered, the expected percent reduction is displayed in a third column. When you have completed all desired changes, enter "A" to return to menu I {C1}. At this point in the program, the other plan may be selected for a second pest management strategy.

Modifying Cone and Seed Factors

Return to menu I {M2} and you can view menu I {S1} by selecting "Orchard Parameters." In menu I {S1} you can modify the default distribution of strobilus stages over a 23-month period and the parameters for seed quality and quantity. If necessary, you can reset the modified values or distributions to the default values for slash pine.

```
I {S1}

            Morphological Stages of Strobili
                Quality/Quantity of Seed

                                                Enter
Modify Parameters

   Distribution of Strobilus Stages               1
   Parameters for Seed                            2

Cancel, Return to Previous Menu                   C
Accept Current Values                             A

                                                 [__]
```

Distribution of Cone Stages

Menu I {S2} presents the default distribution of strobilus stages.

```
I {S2}

        MODIFY DISTRIBUTION FOR THE OCCURRENCE OF DIFFERENT
              MORPHOLOGICAL STAGES OF FEMALE STROBILI

      DEFAULT DISTRIBUTION
                    Month No.
Stage           Begins  Ends
_____________   ______  ____

Bud                0     0.5   Specify new distribution      1
Flower             0     2     Cancel, restore default
Early conelet      3     5       distribution                2
Late conelet       7     9     Continue to next menu         C
Cone              12    13
Green cone        17    19                                 [__]
Ripe cone         20    21
Open cone         22    23

Note:  New distributions will replace the defaults for future simulations.
       The defaults, however, can be restored by entering 2.
```

Three options are provided:

• "Specify new distribution" proceeds to menu I {SC1} where you can modify the distribution of morphological stages for both plans simultaneously.

• "Restore default distribution" deletes any changes you made to the distribution of morphological stages for both plans and restores the default distribution.

• "Continue to next menu" continues without prompting you to modify the distribution.

I {SC1}

MODIFY DISTRIBUTION FOR THE OCCURRENCE OF DIFFERENT MORPHOLOGICAL STAGES OF FEMALE STROBILI

DEFAULT DISTRIBUTION

Stage	Month No. Begins	Month No. Ends
Bud	0	0.5
Flower	0	2
Early conelet	3	5
Late conelet	7	9
Cone	12	13
Green cone	17	19
Ripe cone	20	21
Open cone	22	23

Enter Month Number that each stage:

Begins	Ends
[____]	

Year:	1	2
Jan	1	13
Feb	2	14
Mar	3	15
Apr	4	16
May	5	17
Jun	6	18
Jul	7	19
Aug	8	20
Sep	9	21
Oct	10	22
Nov	11	23

New numbers representing months (entered to the nearest tenth of a month) for each morphological stage of strobilus development listed must be entered. As you enter each month number, the entry brackets [____] will move forward to the next month, prompting you to enter data until you complete the new table in the center of the screen.

```
I {SC1}
_____________________________________________________________________________

          MODIFY DISTRIBUTION FOR THE OCCURRENCE OF DIFFERENT
                MORPHOLOGICAL STAGES OF FEMALE STROBILI
_____________________________________________________________________________
                                   | Enter Month Number   | Year: 1   2
      DEFAULT DISTRIBUTION         |  that each stage:    |
                   Month No.       | ____________________ | Jan    1  13
  Stage            Begins   Ends   |  Begins      Ends    | Feb    2  14
                                   |                      | Mar    3  15
  ____________     ______   ____   | ____________________ | Apr    4  16
  Bud                 0      0.5   |  [__0.2]   [__0.6]   | May    5  17
  Flower              0      2     |  [__0.2]   [__2__]   | Jun    6  18
  Early conelet       3      5     |  [__2__]   [__6__]   | Jul    7  19
  Late conelet        7      9     |  [__7__]   [_10__]   | Aug    8  20
  Cone               12     13     |  [_12__]   [_14__]   | Sep    9  21
  Green cone         17     19     |  [_16__]   [_18__]   | Oct   10  22
  Ripe cone          20     21     |  [_19__]   [_21.5]   | Nov   11  23
  Open cone          22     23     |  [_22__]   [_23__]   |
_____________________________________________________________________________
          Do you want to change any of the values entered?  [___]  Y/N
```

When you have made all entries, a prompt will appear at the bottom of the screen allowing you to change the monthly values just entered. If you select "Y" (yes), the prior monthly values will be erased, and new values can be entered. If you select "N" (no), the program will return to menu I {S1}. At this point, you can accept (A) or cancel (C) the modified distribution of morphological stages of (1) strobili or modify the parameters for seed (2).

Parameters for Seed

If you select "Parameters for Seed," the program will proceed to menu I {S3}.

```
I {S3}

CHOOSE OPTION
CHANGE SEED VALUES

                    CHANGE PARAMETERS FOR SEED VALUES IN:

                         Plan A                  1
                         Plan B                  2
                         Change both plans       3

                         Continue simulation     C

                                  [__]
```

You may modify the default values for seed quality and quantity by selecting Plan A, Plan B, or both plans, and the program will proceed to menu I {S4}.

```
I {S4}

CHANGE SEED VALUES

   Factor                        Value     Code
   Potential No. seed/cone       170         1
   Total No. seed/cone            58         2

   % Seed bug                     10.2       3
   % Empty                        18.8       4
   % Seedworm                       .890     5
   % Unknown                        .4       6
   % Extracted from cones         66         7
   % Germination failure          18.1       8

   % Unextracted seed in cones damaged by:
      Thrips                      67         9
      Coneworms                   57        10
      Other insects               50        11
      Unknown factors             50        12      [___] Enter code
   Continue (finished making changes)        C
```

Each of the values listed can be modified by entering the appropriate code number and, when additional entry brackets [____] appear, a new value. For example, to change the potential number of seeds per cone from 170 to 160 and the percentage of seed bug-damaged seed from 10.2 to 8.5, you enter code number "1" first. When an additional set of brackets appears, you enter the value 160. Next, you enter the code number "3" and the 8.5 percentage figure for seed bug damage. When you have completed modifications, enter "C" in the input brackets to return to menu I {S3}, where you enter "C" to return to menu I {S1}.

You can once again select any option in menu I {S1}. When you choose the "Accept Current Values" option, the current values for the distribution of strobilus stages and parameters for seed are written into temporary files and the program returns to menu I {M2}.

View or Print Results

When you select the option "Accept Current Values" from menu I {M2}, the program will execute the Simulate, Outdata, and Print modules and display menu I {O2}.

```
I {O2}

VIEW RESULTS OF THE SIMULATIONS
_____________________________________________________________

                                             Display on:
    Results of simulation                  Screen     Printer
    _______________________________________________________

    Causes of Cone Damage  . . . . . . . . . . .  1         2
    Cone Life Table . . . . . . . . . . . . . . . 3         4
    Cone Survival Curve . . . . . . . . . . . . . 5         6
    Distributions of Cones:
        Healthy Cones . . . . . . . . . . . . . . 7         8
        Live Damaged Cones  . . . . . . . . . . . 9        10
        Dead, Previously Damaged Cones  . . . . . 11       12
    Orchard Status Table  . . . . . . . . . . . . 13       14
    Seed Analysis . . . . . . . . . . . . . . . . 15       16
    LEAVE THIS PROGRAM --> Economic Analysis  . . .  R
    ________________________________________________________
                                                    [__]
```

You can select any code number (1 through 16) to view the results on the screen or to print them on a printer. When you finish viewing or printing the results, select "R" for "LEAVE THIS PROGRAM --> Economic Analysis" to display menu I {E1} and begin an economic analysis and comparison of the two management plans simulated.

Economic Analysis

Estimates of pesticide application costs are presented for each plan in menu I {E1}. Zeros are listed in the cost per acre columns when no pesticides are used for either plan. If pesticides were used, a default cost is displayed in the cost per acre column.

```
I {E1}

     ECONOMIC ANALYSIS
     ____________________________________________________________

     Change values(s) as needed by entering the appropriate number
     Costs are suggested per your application design

                                    PLAN        COST/ACRE
    Pesticide                      A     B    PLAN A   PLAN B
    ____________________________________   ________________

    Acephate                       1     6    0          0
    Azinphosmethyl                 2     7    0          0
    Bacillus thuringiensis         3     8    0          0
    Fenvalerate                    4     9    0          0
    Malathion                      5    10    0          0
    Finished with entries              F
    Cancel, Return to Previous Menu    Q    ________________
    ______________________________________

    Pesticide                No. [__]
```

These values can be modified by entering a code number for a listed pesticide (1 through 10). The default cost per acre will appear in the lower right side of the menu, and you can enter a new cost per acre. The new cost will be offset in the cost per acre column to remind the user of the new value. These changes are temporary and apply only to the current simulation.

Select "Finished with entries" to continue to menu I {E2} where you may enter additional pesticide application costs. Costs, such as spray adjuvants, labor, and equipment, are entered as summed totals per acre.

```
I {E2}

    ECONOMIC ANALYSIS
    ____________________________________________________________

    Additional costs can also be entered to better estimate
    the costs of your pest management program.

    You may enter any SUMMED total of additional costs.

          Enter additional summed costs/acre:   [ __] for Plan A

          Press the RETURN or ENTER key with or without cost entry


    ____________________________________________________________

    NOTE: An entry is required for Plan A and then Plan B
```

The program will then display a series of tables listing the results of the economic analysis. This analysis includes estimates for harvest yields of cones and seeds on a per acre and total orchard basis, a summary of the pesticide applications used for Plans A and B, and comparative costs per germinable seed for Plans A and B to illustrate the relative economic gains achieved through the different management choices.

Four options are presented at the bottom of the last table:

- "Restart Analysis" returns to menu I {E1}, substitutes new cost figures, and restarts the economic analysis. This can be done as often as desired for the two current management plans.

- "Main Menu" deletes all temporary modifications pertaining to the current analysis and returns to the program's opening menu.

- "Print a Report" prints a report on the economic analysis.

- "Exit to DOS" exits to the MS-DOS prompt.

Select "Print a Report" to view menu I {E6} and enter general information for a report header.

```
I {E6}

______________________________________________________________

ORCHARD AND MANAGER IDENTIFICATION
______________________________________________________________
Enter the following information:

Company or Organization [____________________________________]
Orchard Name or Number  [____________________________________]
Address                 [____________________________________]
                        [____________________________________]
                        [____________________________________]
Manager                 [____________________________________]
Date                    [____________________________________]
Species of pine         [____________________________________]

         Do you want to change entries? Y/N          [_]
```

A sample report is illustrated in Appendix I.

How SeedCalc Works

Files

Sixteen permanent data files (those with the filename extension ___.DAT) containing default values for the system are provided with SeedCalc. The integrity of the ___.DAT files is maintained by transferring them to temporary files (those with the filename extension ___.SIM) before entering user-modified values. The ___.SIM files can be modified but are temporary because SeedCalc resets them to the default values permanently stored as ___.DAT files at the beginning of each simulation. For example, when the pesticide azinphosmethyl is used in a simulation, data is copied from the GUTH.DAT file into the DCIDE.SIM file. If you modify the default values, the new user-modified values replace the values present in the DCIDE.SIM file, while those in the GUTH.DAT file remain unchanged. Permanent changes to the permanent data files (___.DAT files) can be effected by using supplementary program modules.

Simulation Process

The simulation process is partially depicted in figure 3 for three outcomes of coneworm attack: (1) death of the strobili within a short period of time, (2) death of the strobili during a later stage of development, or (3) deformity of strobili with subsequent reduced amounts of seed. To simplify figure 3, months have been compressed and replaced with a few morphological stages of strobilus development as described by Croker (1971). The initial number of flower buds (the "source" of initial strobili) entered by the user for a simulation is stored in the data file COMM.DAT. "State variables" represent the total number of strobili present during each stage of development. "Sinks" are repositories used to accumulate seed or dead strobili.

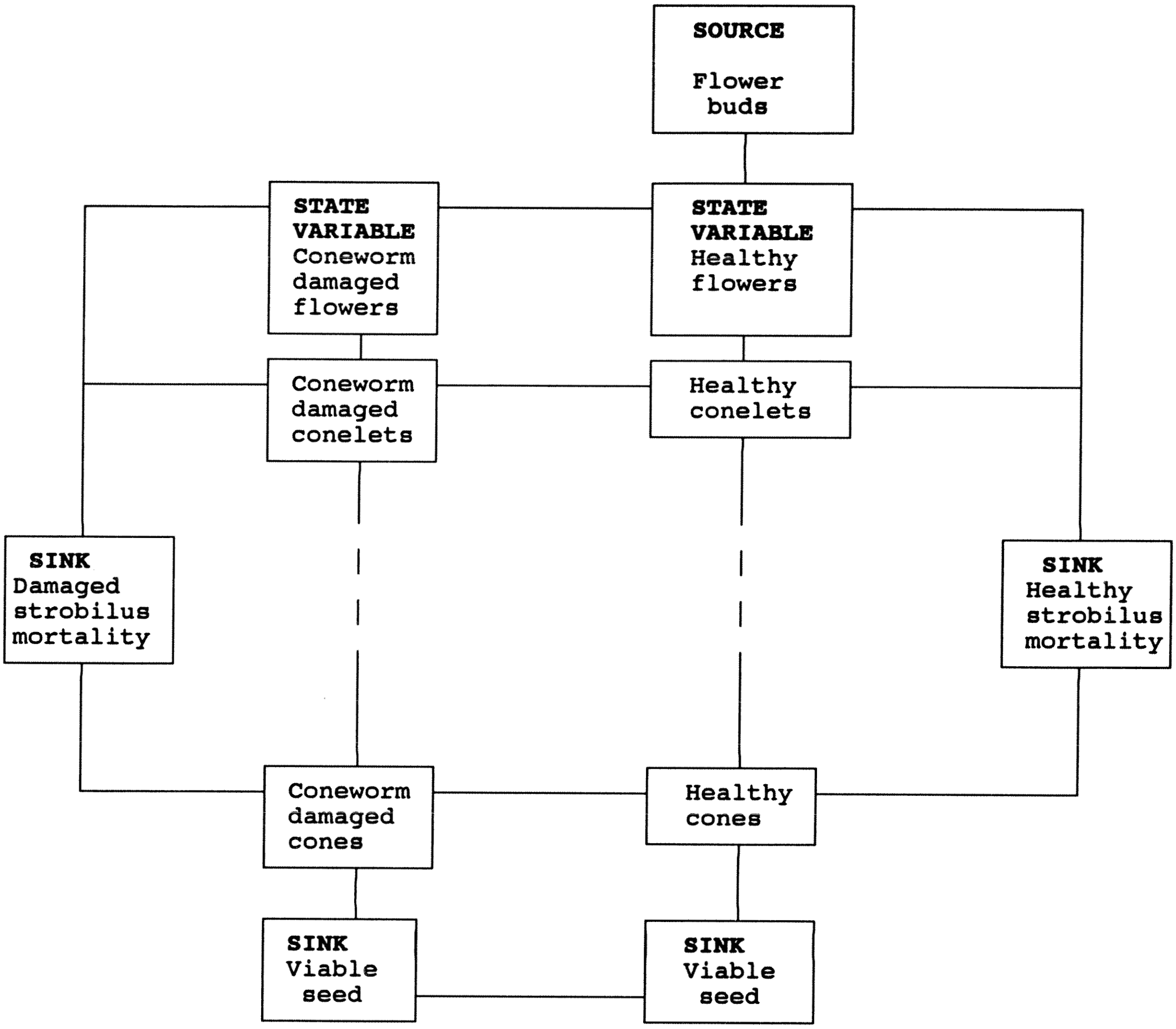


Figure 3—Simplified simulation for coneworm damage to strobili of slash pine. The numbers of strobili that flow out of state variables are determined by age-specific-flow equations. Healthy strobili killed during the same interval flow into a sink for mortality of healthy strobili. Nonlethally damaged strobili pass into state variables for coneworm-damaged strobili and may later pass into a sink for mortality of damaged strobili. Seed yields of damaged strobili are decreased before passing into the sink for viable seed.

As SeedCalc simulates the development of strobili, they progress from the source value through a series of state variables and end in sinks for dead cones and sinks for viable seed. One set of the state variables accounts for healthy strobili. As long as the strobili remain healthy, they progress through this set of state variables as they mature from flowers to open cones. However, when strobili are damaged by pests or other factors, they either pass into a second set of state variables for damaged strobili or accumulate in a sink for mortality of healthy strobili.

In figure 3, healthy strobili attacked and killed by coneworms in the same month accumulate directly into the sink for mortality of healthy cones. Healthy strobili that receive nonlethal attacks accumulate in the set of state variables for coneworm-damaged strobili. Coneworm-damaged strobili that die during a later stage of development accumulate in the sink for mortality of damaged strobili. The yields of seed from nonlethally damaged strobili are reduced by an appropriate amount when they flow from the state variable for coneworm-damaged strobili into the sink for viable seed. For coneworms, this reduction may be as high as 75 percent of the seed expected from healthy cones or 100 percent when damaged or distorted strobili are not collected in the field. The system is conservative in that all initial strobili (or their equivalents in seed) can be accounted for throughout the simulation process by summing the numbers present in the state variables and sinks.

In SeedCalc, different sets of state variables account for different causes of damage because the type of initial damage may affect subsequent mortality rates of strobili and expected yields of seed. Consequently, different rates of pest attack and pest-induced mortality are applied to strobili in each of the state variables.

Program Modules

SeedCalc provides estimates of strobilus and seed production, pest damage, and the efficacy of pest management strategies imposed in two simulated management plans. These estimates are produced through interactions of 14 system modules as illustrated in figure 2. Modular programming techniques were used in developing SeedCalc to facilitate coding, testing, modifying, and updating programming strategy.

In this section, we describe how the individual system modules operate and provide illustrations for management Plan A; similar processes for Plan B result in arrays and variables prefixed with "N." For example, the array MORT(23,4) (described on page 38) contains estimates for the mortality of strobili used in Plan A; array NMORT(23,4) contains similar estimates but is used in Plan B.

Graphics

The Graphics module (GRAPHICS.EXE) allows automatic or manual configuration of SeedCalc to use the maximum graphics capability of a user's computer system. Selecting the highest graphics capability provides a better display of SeedCalc's screen information. Incompatibility of some graphic cards can be minimized by selecting the option "A: Monochrome (MDA) for low resolution text only" from the menu for manual installation. When the graphics installation is completed, the necessary values are stored in the COMM.DAT file.

Starting SeedCalc

The SeedCalc module (SEEDCALC.EXE) will start SeedCalc (after it is installed the first time). The program version number is displayed, as well as identification of the program process, i.e., initiating a simulation, obtaining system information, or exiting to DOS.

Opening Menu

The Choice module (CHOICE.EXE) directs program execution to the interactive program (Main Module), to the tutorial (DEMO.EXE), or to DOS (to leave the SeedCalc system).

Supplementary Information

The Information module (INFO.EXE) provides information describing SeedCalc's general structure, hardware and software requirements, and how to contact the programmers; and it allows return to the main menu.

Entering Orchard Size

The Orchard Size module (MAIN.EXE) prompts keyboard entry of the initial number of female strobili and the number of acres used in a simulation. These two values are stored as the variables LIVE$ and ACRES$ in the COMM.SIM file. This module also transfers default data from the permanent files to the temporary files used for each simulation. An error message will indicate when any of SeedCalc's permanent files are missing from the directory.

Once the initial data are stored, several management choices are available. The pest damage rates module (PEST.EXE), pesticide applications module (CHEM.EXE), and orchard parameters modules (SURVEY.EXE and CH_SFMO.EXE) can be used to change SeedCalc's default values before running the full simulation. When all changes are completed, the program writes several variables to the COMM.SIM and other ___.SIM files and proceeds to the simulation module (SIMULATE.EXE).

Pest Damage

The Pest Damage module (PEST.EXE) provides for modification of the default values used to simulate monthly injury and mortality rates for strobili. The default values are copied from the MORT.DAT, ATTACK.DAT, and ATMORT.DAT files and are stored as arrays (MORT(23,4), NMORT(23,4), ATK(23,4), NATK(23,4)), and MORT.ATK(23,4). The values in these arrays can be modified by the user and stored as either temporary (__.SIM) or permanent (__.DAT) files for later use.

Data stored in the ___.SIM and ___.DAT files represent monthly rates of pest attack and pest-caused mortality of strobili. The system accommodates damage percentages for each of four pest categories: (1) slash pine flower thrips, (2) coneworms, (3) unidentified insects, and (4) unknown factors. Any combination of modified rates of attack and mortality can be entered.

Combinations of percentages entered by user

Attacks	Mortality	No. of categories
Yes	Yes	1-4
Yes	No	1-4
No	Yes	1-4
No	No	1-4

SeedCalc's response to different combinations of user-entered attack and mortality percentages follows:

• When percentages for either new attack or mortality rates are entered alone, the proportion of change from the default rate to the new rate is calculated and used to modify the default values of the missing rate. For example, when an attack rate is entered, then mortality rate = (new attack percent/old attack percent) x old percent mortality.

• When percentages for both attack and mortality rates are entered for a given pest category, both percentages are used.

• When neither attack nor mortality percentages are entered, the new arrays will contain the original default values. If zero data is intentionally entered for a pest category, the zeros are maintained as values for the new rates.

• The proportions of previously attacked strobili that die each month cannot be modified because we assumed that these proportions remain the same as those in the default distribution.

Damage rates can be modified on a monthly or global (total) basis. Monthly modifications require entry of a month number and the percentages of strobili attacked and killed by category. The system replaces default percentages for attack and mortality rates with the newly entered percentages for the category selected. Default distributions of other categories are not affected unless specifically selected for change. Global modifications are made by entering estimates of the total rates of attack and mortality for a 23-month period. These percentages are based on the initial number of strobili in the orchard at flowering (similar to the 100 rx column of life tables). SeedCalc distributes these new percentages over a 23-month period so that they parallel the default distributions for rates of attack and mortality. The new distributions of damage are similar to default distributions, but they reflect the changed rates of mortality and attacks entered for each pest category selected. It is assumed that the proportions of previously attacked strobili that die each month will be the same as those in the default distribution.

We used survey data (Fatzinger and others 1980) collected from 1973-74 in a slash pine seed orchard to develop default values for pest damage. Pest damage simulation is illustrated with these values. The survey used monthly observations taken on a 20 percent random sample of strobilus clusters located in the crowns of 18 trees (9 clones x 2 ramets per clone) starting with a total of 1,059 sample flower buds during January 1973 (table 1). Seed extracted from mature sample strobili (cones) were radiographed to determine the incidence and causes of damage and were germinated to determine seed viability.

The probabilities of pest damage during different stages of strobilus development vary widely from orchard to orchard and from year to year. Pest damage on an individual orchard can probably be predicted more accurately using data from surveys of individual seed orchards. Using data from the IMS or the SPMS is recommended because the procedures in these systems control for differences in clonal variation. SeedCalc uses tabulated default values of the average proportions of cones and seed affected by pests and other factors as estimates from survey data taken in the Southeastern United States (Fatzinger and others 1980, 1990). These tabulations represent the proportions of cones remaining in an orchard at monthly intervals. In developing SeedCalc, we assumed that the proportion of cones attacked is independent of the number of cones present on the orchard trees. We also assumed that a cone protected from one destructive agent remains susceptible to attack by other agents as it passes through later developmental stages.

Current mortality default values are listed in table 2 as the monthly proportions of healthy cones attacked and killed during the same month. Each proportion represents the number of cones killed each month by a pest divided by the number of healthy cones remaining on the trees during the previous month. For example, a total of 102 cones were killed during February of the first year—72 cones were killed by thrips, 5 by other insects, and 25 by unknown factors. At the end of January (during the February observation) 883 cones remained in the sample (table 1). The proportion of the 883 cones killed during February by thrips was 72/883 = 0.082, by other insects was 5/883 = 0.005, and by unknown factors was 25/883 = 0.028 (table 2).

Current damage default values are listed in table 3 as the monthly proportions of healthy cones attacked but not killed during the same month. These proportions represent the number of cones damaged each month divided by the number of healthy cones that remained the previous month. For example, 153 cones were attacked by thrips during February of the first year and 72 of these died. The proportion of damaged cones for February is (153-72)/883 = 0.092.

Delayed mortality default values are listed in table 3 as the monthly proportions of previously damaged cones that either die from the previous injury or are killed directly by a second attack. The proportions of cones killed apply to the individual categories of damaged cones, i.e., "TAK" applies only to strobili previously attacked by thrips, "DAK" applies only to strobili previously attacked by coneworms, etc. These proportions were calculated by dividing the numbers of previously attacked cones that died each month by the accumulated number of damaged live cones remaining the previous month. For example, 67 of the cones previously damaged by thrips died during February. Because a total of 114 cones remained in the state variable for cones damaged by thrips, 67/114 = 0.588 is listed for "TAK" in the month of February of the first year.

At cone maturity, the surviving cones are converted into seed equivalents by multiplying the number of healthy cones by the average number of seed expected to be present in a healthy cone. Proportions of seed removed from damaged cones depend on the average expected seed loss from different agents. The four categories representing causes for seed losses in SeedCalc follow:

TKS = thrips killed seed
DKS = coneworm killed seed
IKS = other insect killed seed
UKS = seed killed by unknown factors

The amount of seed obtained from both healthy and damaged cones is further reduced by the average proportion of seed lost during the seed extraction process. Representation of seed lost during extraction in SeedCalc follows:

$$E = SF + EF + UF$$

where

E = average proportion of seed lost during extraction to all factors,
SF = proportion of unopened scales,
EF = proportion lost due to the extraction method, and
UF = proportion lost to unknown factors.

The total number of viable seed is estimated by applying a nonviable seed factor to the total number of seed extracted. Calculating the nonviable seed factor, representing the average proportions of extracted seed damaged, follows:

$$Z = SK + LK + UK$$

where

Z = average proportion of extracted seed lost to all factors,
SK = proportion lost to seed bugs,
LK = proportion lost to seedworms (*Cydia* spp., formerly *Laspeyresia)*, and
UK = proportion lost to unknown factors.

The default values used in SeedCalc for seed quality follow:

Factor	Default value
TKS	0.67
DKS	.5
IKS	.5
UKS	.5
SF	0
EF	.66
UF	0
SK	.102
LK	.0089
UK	.004
POT	170
Y	58
EK	188
GF	181

Pesticide Application

Three primary assumptions underlie the simulation of pesticide applications in SeedCalc: (1) pesticide efficacy varies between species of pests and seasons of application; (2) these differences result in differential rates of control for each pest, e.g., a February application of malathion may result in 50 percent control of thrips but only a 10 percent control of coneworms; and (3) a pesticide will affect cone survival and pest attack rates only during the month of application.

The Pesticide Application module (CHEM.EXE) is used to modify default values stored in several of SeedCalc's data files. These modifiable files are used to simulate the efficacy of different pesticides and methods of application. The default values are averages of monthly estimates for the efficacy of pesticides derived primarily from the literature, unpublished studies, and surveys. Only a few estimates of the monthly efficacy of pesticides for control of cone and seed insects were available in the literature. Most references provided estimates of the overall effectiveness of different pesticides in reducing damage to cones and seed over a 1- or 2-year period.

Array ECON.CHEM$(25,2) is created by the Pesticide Application Module and is stored in temporary file ECON.SIM. This array contains 25 elements of information about Plans A and B. The first 23 elements represent a list of the pesticides selected and the months during which each pesticide is applied for a particular simulation. The method selected for applying pesticides is stored in array element 25.

The values in file SEED1.DAT and SEED2.DAT are used to modify the default values for quality and quantity of seed expected from untreated trees of slash pine. User modifications of this data either by simulation of pesticide applications or by entry of new values for seed quality and quantity are stored in files SEED1.SIM and SEED2.SIM. Default values for the effects of pesticides on the quality and quantity of seed were taken from the literature and results of unpublished studies (tables 4-6) and are summarized in table 7.

Estimates of the percent reductions in rates of monthly pest damage attributable to pest management Plan A are stored in the first 23 elements of array DCIDE(25,4). Default values for DCIDE(25,4) are taken from the permanent storage files ASAN.DAT, BT.DAT, CYTH.DAT, GUTH.DAT, and ORTH.DAT. The array DCIDE(25,4) is transferred to the temporary data file DCIDE.SIM. The values in these arrays equal zero when no pesticide applications are made. The values stored in DCIDE.SIM are used to replace array DCIDE(25,4) values in subsequent modules of SeedCalc. The reproduced array is then used to modify the values of arrays MORT(23,4) and ATK(23,4):

MORT(23,4) = MORT(23,4) x (1-DCIDE(1-23,1-4) x DCIDE(25,1)
ATK(23,4) = ATK(23,4) x (1-DCIDE(1-23,1-4) x DCIDE(25,1)

where

ATK(23,4) and MORT(23,4) are arrays containing estimates of the percentages of strobili attacked and killed, respectively, for Plan A during each of 23 monthly periods.

1-DCIDE(1-23,1-4) represents the first 23 elements of array DCIDE(25,4) for Plan A, each of which is subtracted from 1 before its use in modifying the attack and mortality rates for survival of strobili.

DCIDE(25,1) is the 25th element of the array for Plan A that contains estimates of the effectiveness of a particular method of pesticide application.

Values in the permanent storage files ASAN.DAT, BT.DAT, CYTH.DAT, GUTH.DAT, and ORTH.DAT reflect the average efficacy of five pesticides for control of cone and seed insects:

Data storage file	Array contained in file	Pesticide
ASAN.DAT	ASAN(23,4)	Fenvalerate[2]
BT.DAT	BT(23,4)	*B. thuringiensis*
CYTH.DAT	CYTH(23,4)	Malathion
GUTH.DAT	GUTH(23,4)	Azinphosmethyl
ORTH.DAT	ORTH(23,4)	Acephate

[2] At the time SeedCalc was developed, monthly data about the efficacy of synthetic pyrethroids was available only for the insecticide fenvalerate.

Each array contains 23 monthly estimators for the efficacy of the pesticide in reducing mortality caused by thrips, coneworms, unidentified insects, and unknown factors. This efficacy data was taken from summaries of the literature and the results of unpublished studies and surveys (tables 8-11).

The user specifies pesticide applications on a monthly basis either by entering the month number for each application accompanied by the pesticide to be used (= custom design) or by selecting a conventional spray schedule that assigns a month number for each application of the pesticide selected. The conventional schedule can be modified by deleting individual applications. The array DCIDE(25,4) is then compiled using the default or modified values present in the pesticide arrays. These default values, which apply only to the month when the pesticide is applied, are listed in tables 12-16.

The default values used in SeedCalc for the efficacy of pesticides are estimates for hydraulic sprayer applications. These are further modified in the program when application methods other than hydraulic spraying are selected. Few studies have compared the relative efficacy of the different methods of pesticide application in southern pine seed orchards. To simulate the effect of using different methods of application, we obtained average values of the relative efficacy of different application methods from the literature and the results of unpublished studies (table 17).

Relationships of the efficacy for different methods of pesticide applications developed for use in SeedCalc follow:

Method	Average % R[3]	Efficacy ratio
Hydraulic sprayer	89.7647	1.00
Mistblower	75.5455	.84
Aerial sprayer	65.2500	.73

[3]Overall averages for percent control (see table 17).

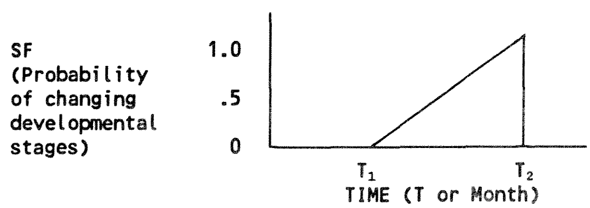
Cone and Seed Factors

This module (SURVEY.EXE) can be used to modify the simulated phenology of female strobilus development by interfacing with module CH_SFMO.EXE and by modifying seed parameters. Eight morphological stages of development for female strobili are represented in SeedCalc: (1) flower buds, (2) flowers, (3) early conelets, (4) late conelets, (5) cones, (6) green cones, (7) ripe cones, and (8) open (harvested or collected) cones. SeedCalc tracks the development of female strobili through these eight stages according to the monthly distribution of default values in file STAGER.DAT:

	Month No.	
Stage	Begins (T_1)	Ends (T_2)
Bud	0	0.5
Flower	0	2
Early conelet	3	5
Late conelet	7	9
Cone	12	13
Green cone	17	19
Ripe cone	20	21
Open cone	22	23

The distribution of these values can be "permanently" changed for both plans by modifying the default values in file STAGER.DAT. The default values, however, can be restored by copying the BKSTAGER.DAT file into the STAGER.DAT file.

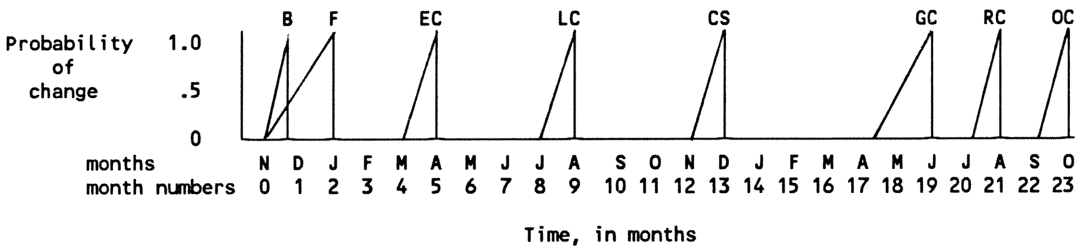
The development of strobili through each of the eight morphological stages of development is assumed to follow a piece-wise linear function:



where

T = Current month number (1 - 23),
T_1 = Month number at which stage of strobilus development begins, and
T_2 = Month number at which stage of strobilus development ends.

The probability of change before time T_1 is zero. Morphological changes occur during the time interval T_1 to T_2, but the change is not assumed to be instantaneous. At the end of the time interval, i.e., after T_2, the probability of change will return to zero until the time interval for changing to a subsequent morphological stage is reached:



where

B = flower buds,
F = flowers,
EC = early conelets,
LC = late conelets,
CS = cone stage,
GC = green cones,
RC = ripe cones, and
OC = open (harvested or collected) cones.

The formulae for generating changes from one morphological stage to the next as strobili pass through the 23 monthly state variables follow:

If $T < T_1$, SF = 0
If $T_1 <= T <= T_2$, SF = $(1/(T_2 - T_1))*(T - T_1)$
If $T > T_2$, SF = 0

where

SF = Stage Factor used to assign morphological stages of development.

The default values for T_1 and T_2 are the beginning and ending months, respectively.

It is assumed that the cones are collected at the end of the ripe cone stage and that the seed are extracted immediately after cone collection:

If $< T_1$, SF = 0
If $T_1 <= T <= T_2$, SF = 1.0
If $T > T_2$, SF = 0

Strobili are converted to seed equivalents after they reach the last stage of development. The following seed parameters can be modified for either or both plans:

- Potential No. seed per cone
- Total No. seed per cone
- % Seed bug
- % Empty
- % Seedworm
- % Unknown
- % Extracted from cones
- % Germination failure
- % Unextracted seed in cones damaged by
  - Thrips
  - Coneworms
  - Other insects
  - Unknown factors

Simulate Results

Data stored in temporary files (___.SIM files) are recalled in the Simulation module (SIMULATE.EXE) to modify default rates of strobilus damage and mortality. Information for different formulations of Plans A and B was entered and stored in these temporary files during operations of the Pest Damage Rate module, the Pesticide Application module, and the Orchard Parameter module. The default rates represent "average" strobilus damage without pest management. The modifications of these default rates represent the different user formulations of management Plans A and B.

The rates in the pest damage arrays are modified by rates in the DCIDE.SIM file, which contains estimates for efficacy of pesticide applications.

MORT(23,4) = MORT(23,4) x (1-DCIDE(1-23,1-4) x DCIDE(25,1)
ATK(23,4) = ATK(23,4) x (1-DCIDE(1-23,1-4) x DCIDE(25,1)

where

MORT(23,4) = strobilus mortality rates, Plan A
DCIDE(23,4) = efficacy of pesticide
DCIDE(25,1) = efficacy of pesticide application method
ATK(23,4) = strobilus damage rates, Plan A

Note: For a detailed explanation of these arrays see the section on "Pesticide Applications Module."

Morphological stages of female strobilus development (Croker 1971) are assigned to each of the 23 months of strobilus development as described in the section on cone and seed factors. The number of strobili injured or killed each month are calculated for each of four categories: (1) thrips, (2) coneworms, (3) other insects, and (4) unknown. The following is an example of the calculations for the slash pine flower thrips.

Calculations for thrips (J = 1):

TAK(I) = MORT.ATK(I, J) x TA(I - 1)
TA(I) = ATK(I, J) x HELTHY(I - 1) - TAK(I) + TA(I - 1)
TD(I) = MORT(I, J) x HELTHY(I - 1)
MTA(I) = ATK(I, J) x HELTHY(I - 1) + TD(I)

where

I = month number
J = factor number (for thrips, J = 1)
TAK(I) = number of dead strobili previously damaged by thrips
TA(I) = number of healthy strobili attacked but not killed by thrips
TD(I) = number of healthy strobili attacked and killed by thrips
MTA(I) = number of thrips attacks (lethal + nonlethal)
HELTHY(I) = number of healthy strobili
MORT(I,J) = proportions of healthy strobili dying during month I due to factor J
ATK(I,J) = proportion of healthy strobili injured during month I by factor J
MORT.ATK(I,J) = proportions of previously damaged strobili dying during month I due to factor J

The same calculations are preformed for the effects of the other three factors on the conditions and numbers of strobili. Note that the D indicates coneworms, the I indicates insects, and the U indicates unknown factors.

Calculations for coneworms (J = 2):

DAK(I) = MORT.ATK(I, J) x DA(I - 1)
DA(I) = ATK(I, J) x HELTHY(I - 1) - DAK(I) + DA(I - 1)
DD(I) = MORT(I, J) x HELTHY(I - 1)
MDA(I) = ATK(I, J) x HELTHY(I - 1) + DD(I)

Calculations for other insects (J = 3):

IAK(I) = MORT.ATK(I, J) x IA(I - 1)
IA(I) = ATK(I, J) x HELTHY(I - 1) - IAK(I) + IA(I - 1)
ID(I) = MORT(I, J) x HELTHY(I - 1)
MIA(I) = ATK(I, J) x HELTHY(I - 1) + ID(I)

Calculations for unknown factors (J = 4):

UAK(I) = MORT.ATK(I, J) x UA(I - 1)
UA(I) = ATK(I, J) x HELTHY(I - 1) - UAK(I) + UA(I - 1)
UD(I) = MORT(I, J) x HELTHY(I - 1)
MUA(I) = ATK(I, J) x HELTHY(I - 1) + UD(I)

The total numbers of healthy, injured, and dead strobili are estimated over all damage categories at monthly intervals.

SUM.MORT.ATK(I) = TAK(I) + DAK(I) + IAK(I) + UAK(I)
SUM.ATK.LIVE(I) = TA(I) + DA(I) + IA(I) + UA(I)
SUM.MORT(I) = TD(I) + DD(I) + ID(I) + UD(I)
MSUM.ATK.LIVE(I) = MTA(I) + MDA(I) + MIA(I) + MUA(I)
TOT.DEAD(I) = SUM.MORT(I) + SUM.MORT.ATK(I)
HELTHY(I) = HELTHY(I - 1) + SUM.ATK.LIVE(I - 1) - TOT.DEAD(I) - SUM.ATK.LIVE(I)
LIVE(I) = HELTHY(I) + SUM.ATK.LIVE(I)
CSINK = CSINK + SUM.MORT(I)
DCSINK = DCSINK + SUM.MORT.ATK(I) + OVER.DEAD
PC.SURV(I) = LIVE(I) / LIVEX x 100
ACC.DEAD(I) = CSINK + DCSINK

where

SUM.MORT.ATK(I) = total number of previously injured strobili dying during month I
SUM.ATK.LIVE(I) = total number of healthy strobili injured during month I
SUM.MORT(I) = total number of healthy strobili killed during month I
MSUM.ATK.LIVE(I) = total number of healthy strobili attacked during month I (lethal + nonlethal attacks)
TOT.DEAD(I) = total number dead strobili at month I
LIVE(I) = total number of live strobili (healthy + injured)
CSINK = total number of healthy strobili injured and dying the same month
DCSINK = total number of strobili injured during one month but dying during a later month
PC.SURV(I) = percent survival of strobili at month I
ACC.DEAD(I) = total number of dead strobili

The calculation of quantity and quality of seed at the simulated time of cone harvest follows.

S.A.HC = HELTHY(23) x Y
S.A.TC = TA(23) x TKS x Y
S.A.DC = DA(23) x DKS x Y
S.A.IC = IA(23) x IKS x Y
S.A.UC = UA(23) x UKS x Y
S.A.DAM = S.A.TC + S.A.DC + S.A.IC + S.A.UC
S.E.HC = S.A.HC x (SF + EF + UF)
S.E.DAM = S.A.DAM x (SF + EF + UF)
S.V.HC = S.E.HC x (SK + LK + UK)
S.V.DAM = S.E.DAM x (SK + LK + UK)
S.TOT.V = S.V.HC + S.V.DAM

where

Y = number of seed per healthy cone
_KS = proportion of seed lost in a strobilus damaged by
TKS = thrips
DKS = coneworms
IKS = other insects
UKS = unknown factors
_F = proportion of seed lost during extraction to:
SF = unopened scales
EF = extraction method
UF = unknown factors
_K = proportion of extracted seed damaged by
SK = seed bugs
LK = seedworms
UK = unknown factors
S.A._C = number of seed present in cones
S.A.HC = healthy at harvest
S.A.TC = damaged by thrips
S.A.DC = damaged by coneworms
S.A.IC = damaged by other insects
S.A.UC = damaged by unknown factors
S.A.DAM= damaged at harvest
S.E.__ = total number of seed lost during extraction of
S.E.HC = healthy cones
S.E.DAM= damaged cones
S.V.__ = total number of viable seed in
S.V.HC = healthy cones
S.V.DAM= damaged cones
S.TOT.V= all cones

The simulated data are then written to output files COMM.SIM, DCONE2.SIM, NCONE2.SIM, SEED1.SIM, SEED2.SIM, and SEED3.SIM for use in other modules.

Summarize Results

The Outdata module (OUTDATA.EXE) is used to prepare the results of simulations for management Plans A and B for viewing on the screen or sending to a printer. This module uses estimates produced by the Simulation Module to organize data suitable for the Printing Module.

Information on the survival and damage rates of strobili is calculated and stored in three arrays.

ORCH.LIVE(I,J) = STAG.FAC(I,J) x LIVE(I)
ORCH.ATT.LIVE(I,J) = STAG.FAC(I,J) x SUM.ATK.LIVE(I)
ORCH.ATT.DEAD(I,J) = STAG.FAC(I,J) x SUM.MORT.ATK(I)

where

I = month number
J = Stage factor number (1-8)
ORCH.LIVE(I,J) = No. live strobili by stage
ORCH.ATT.LIVE(I,J) = No. newly attacked strobili by stage
ORCH.ATT.DEAD(I,J) = No. attacked strobili dying by stage
STAG.FAC(I,J) = Stage factor for month I, stage J
LIVE(I) = No. live strobili at month I
SUM.ATK.LIVE(I) = Total strobili attacked at month I
SUM.MORT.ATK(I) = Total attacked strobili dying at month I

Survival data is converted to mortality data for use in producing survival curves for strobili:

INV.PC.MORT(I) = 100 - (PC.SURV(23-I))

where

INV.PC.MORT(I) = percent strobilus mortality for month I
PC.SURV(I) = percent strobilus survival for month I

Calculating estimates of the total numbers of strobili and seed and the effects of damage factors on the yields of strobili and seed follow.

Total numbers of strobili

TOT.TA = $\sum$ MTA(I)
TOT.TD = $\sum$ TD(I)
TOT.TAK = $\sum$ TAK(I)
TOT.DA = $\sum$ MDA(I)
TOT.DD = $\sum$ DD(I)
TOT.DAK = $\sum$ DAK(I)
TOT.IA = $\sum$ MIA(I)
TOT.ID = $\sum$ ID(I)
TOT.IAK = $\sum$ IAK(I)
TOT.UA = $\sum$ MUA(I)
TOT.UD = $\sum$ UD(I)
TOT.UAK = $\sum$ UAK(I)

where

I = month
TOT.xA = number attacked by x
TOT.xD = number killed by x
TOT.xAK = number of prior attacked strobili killed by x
xA(I) = number attacked by x for month I
xD(I) = number killed by x for month I
xAK(I) = number of prior attacks killed by x for month I
MxA(I) = number of lethal + nonlethal attacks in month I
And for x: T = thrips
D = coneworms
I = other insects
U = unknown

Percentages of total strobili
PC.TA = TOT.TA / LIVEX x 100
PC.TD = TOT.TD / LIVEX x 100
PC.TAK = TOT.TAK / LIVEX x 100
PC.DA = TOT.DA / LIVEX x 100
PC.DD = TOT.DD / LIVEX x 100
PC.DAK = TOT.DAK / LIVEX x 100
PC.IA = TOT.IA / LIVEX x 100
PC.ID = TOT.ID / LIVEX x 100
PC.IAK = TOT.IAK / LIVEX x 100
PC.UA = TOT.UA / LIVEX x 100
PC.UD = TOT.UD / LIVEX x 100
PC.UAK = TOT.UAK / LIVEX x 100
TOTPCA = PC.TA + PC.DA + PC.IA + PC.UA
TOTPCD = PC.TD + PC.DD + PC.ID + PC.UD
TOTPCK = PC.TAK + PC.DAK + PC.IAK + PC.UAK
TOTSAM = TOTPCD + TOTPCK
HARV = PC.TA - PC.TD - PC.TAK + PC.DA - PC.DD - PC.DAK + PC.IA - PC.ID - PC.IAK + PC.UA - PC.UD - PC.UAK

where

PC.xA = percent attacked by x
PC.xD = percent killed by x
PC.xAK = percent of prior attacked killed by x
And for x: T = thrips
D = coneworms
I = other insects
U = unknown
LIVEX = number of live strobili
TOTPCA = total percent attack
TOTPCD = total percent of healthy strobili that died

TOTPCK = total percent of prior attacks that died
TOTSAM = total percent dead
HARV = percent harvested

Total numbers of seed:

TOT.SEED = (S.A.HC + S.A.DAM) x DNPC
EXT.SEED = (S.A.HC + S.A.DAM) x EF x DNPC
TOT.EMPTY = TOT.SEED x EK x DSEM
TOT.BUG = TOT.SEED x SK x DSSB
TOT.WORM = TOT.SEED x LK x DSSW
TOT.MALF = TOT.SEED x UK x DSUK
TOT.FULL = TOT.SEED - TOT.EMPTY - TOT.BUG - TOT.WORM - TOT.MALF
TOT.GERM = TOT.FULL x (1 - GF)
CE = HELTHY(23) / LIVE(1)
SE = TOT.FULL / LIVE(23) / POT

where

TOT.SEED = total seed present in all cones
EXT.SEED = total seed extracted from all cones
TOT.EMPTY = total empty seed
TOT.BUG = total seed damaged by seed bugs
TOT.WORM = total seed damaged by seedworms
TOT.MALF = total malformed seed
TOT.FULL = total full seed
TOT.GERM = total seed germinated
CE = cone efficiency
SE = seed efficiency
HELTHY(23) = total healthy cones at harvest (month 23)
LIVE(23) = total live cones at harvest (month 23)
LIVE(1) = total live flower buds (month 1)
POT = total potential seed per cone
GF = proportion of full seed that fail to germinate
DNPC = number of seed per cone
EF = proportion remaining in cone due to extraction method
DSEM = proportion of empty seed
DSSB = proportion of seed damaged by seed bugs
DSSW = proportion of seed damaged by seedworms
DSUK = proportion of seed damaged by unknown factors
xK = proportion of extracted seed damaged by:
And for x: EK = empty seed
SK = seed bugs
LK = seedworms
UK = unknown factors
S.A.xC = number of seed present in cones:
And for x: S.A.HC = healthy at harvest
S.A.DAM = damaged at harvest

View Results

The Print module (PRINT.EXE) provides a screen where the user may select from a number of different options to view the results of simulations run on SeedCalc. This module uses the results of data summaries generated in the Outdata Module and stored in temporary files COMM.SIM, DCONE2.SIM, NCONE2.SIM, OUTPUT.SIM, SURV.SIM, and PCTTOT.SIM. When an option is selected, the module formats the results for sending to either a screen or a printer. When viewing or printing is completed, the program proceeds to the Economic Module.

Economic Analysis

The Economic Module (ECON.EXE) estimates the costs of the pest management programs (Plans A and B). Default values for the pesticides used and application methods are stored in APP_COST.DAT and ECON.SIM.

The default costs per pesticide can be modified by the user. Additional costs per acre (e.g., cost of spray adjuvants, labor, equipment), can be added into the calculations. These values are stored as variables.

Cone and seed yields per acre and by total orchard size for Plans A and B are presented on screen. The user should remember that the reduction rates for the pest populations and damages are based on defined spray windows. Therefore, reduction by hydraulic application is dependent on all trees being sprayed in x number of days to maintain efficacy. The chemical application schedule(s) and the application method(s) are also summarized on screen. Finally, the management plan costs are calculated on a cost per germinable seed.

A user can return to the beginning of the economic analysis and repeat the analysis with the same or different costs or request a printed report. The report option allows the user to enter specific header information (orchard name, manager, tree species) to better delineate the parameters of the management plans. The report includes a chemical cost analysis and yield analysis.

The user can return to the main module and begin a new simulation run or leave the program. Returning to the main module will erase all temporary modifications made during the current simulation.

Literature Cited

Barcia, Dorothy R.; Merkel, Edward P. 1972. Bibliography on insects destructive to flowers, cones, and seeds of North American conifers. Res. Pap. SE-92. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 80 p.

Bramlett, David L.; Godbee, John F., Jr. 1982. Inventory-monitoring system for southern pine seed orchards. Res. Pap. 28. Macon, GA: Georgia Forestry Commission. 18 p.

Coulson, R.N.; Saunders, M.C. 1987. Computer-assisted decision-making as applied to entomology. Annual Review of Entomology. 32:415-437.

Croker, Thomas C. 1971. Female strobilus stages of longleaf pine. Journal of Forestry. 69:98-99.

DeBarr, G.L.; Ebel, B.H. 1974. Conelet abortion and seed damage of shortleaf and loblolly pines by a seed bug, *Leptoglossus corculus*. Forest Science. 20:165-170.

DeBarr, Gary L.; Matthews, Fred R. 1971. Mist-blower applications for control of flower thrips and southern cone rust in a slash pine seed orchard. Journal of Economic Entomology. 64:520-522.

Fatzinger, Carl W.; Hertel, Gerald D.; Merkel, Edward P. [and others]. 1980. Identification and sequential occurrence of mortality factors affecting seed yields of southern pine seed orchards. Res. Pap. SE-216. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 43 p.

Fatzinger, C.W.; Merkel, E.P.; Mantie, R. [and others]. 1984. Control of cone and seed insects in slash pine seed orchards with acephate sprays. Journal of the Georgia Entomological Society. 19:102-110.

Fatzinger, Carl W.; Muse, H. David; Miller, Thomas [and others]. 1988. Estimating cone and seed production and monitoring pest damage in southern pine seed orchards. Res. Pap. SE-271. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 30 p.

Fatzinger, Carl W.; Muse, H. David; Miller, Thomas [and others]. 1990. Survey and pest monitoring system for southern pine seed orchards. Southern Journal of Applied Forestry. 14:147-154.

Fatzinger, Carl W.; Yates, Harry O., III; Barber, Larry R. 1992. Evaluation of aerial applications of acephate and other pesticides for control of cone and seed insects in southern pine seed orchards. Journal of Entomological Science. 27:172-184.

Forrester, Joy W. 1968. Principles of systems. Cambridge, MA: Write-Allen Press, Inc. 400 p.

Merkel, Edward P. 1964. Hydraulic spray applications of pesticides for the control of slash pine cone and seed insects. Res. Pap. SE-9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Merkel, Edward P.; DeBarr, Gary L.; O'Gwynn, Claude H. 1976. Mist blower application of Guthion for cone insect control in slash pine seed orchards. Res. Pap. SE-148. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 8 p.

Merkel, E.P.; Yandle, David O. 1965. Mist blower applications of pesticides for cone insect control on slash pine. Res. Note SE-52. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 4 p.

Sarvas, Risto. 1962. Investigations on the flowering and seed crop of *Pinus sylvestris*. Communicationes Instituti Forestalis Fenniae. 53(4). 198 p.

Starfield, A.M.; Bleloch, A.L. 1986. Building models for conservation and wildlife management. New York: Macmillan. 253 p.

Waters, W.E. 1974. Systems approach to managing pine bark beetles. In: Payne, Thomas L.; Coulson, Robert N.; Thatcher, Robert C., eds. Proceedings, southern pine beetle symposium; 1974 March 7-8; College Station, TX: Texas Agricultural Experiment Station and U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 12-14.

Worner, Susan P. 1991. Use of models in applied entomology: the need for perspective. Environmental Entomology. 20:768-773.

Yates, Harry O., III; DeBarr, Gary L. 1984. Integrated pest management in seed orchards--insects. In: Branham, Susan J.; Hertel, G.D., eds. Proceedings, Integrated forest pest management symposium; 1984 June 19-21; Athens, GA: The University of Georgia, Center for Continuing Education: 166-178.

Tables

Table 1—Survival of female strobili of slash pine over a 22-month period from December 1972 to September 1974 in the McColsky seed orchard near Lake City, FL

Month	No. of cones remaining		No. of dead cones resulting from attacks:			Accumulated No. of cones	
	Healthy	Damaged	This month	A previous month	Total	Dead	Live
Dec	1000	59	0	0	0	0	1059
Jan	883	157	16	3	19	19	1040
Feb	669	189	102	80	182	201	858
Mar	626	108	27	97	124	325	734
Apr	607	112	8	7	15	340	719
May	596	112	2	9	11	351	708
Jun	561	97	34	16	50	401	658
Jul	532	93	26	7	33	434	625
Aug	463	82	67	13	80	514	545
Sep	445	84	13	3	16	530	529
Oct	441	85	1	2	3	533	526
Nov	424	95	6	1	7	540	519
Dec	420	97	2	0	2	542	517
Jan	416	97	4	0	4	546	513
Feb	408	103	1	1	2	548	511
Mar	405	99	3	4	7	555	504
Apr	393	106	3	2	5	560	499
May	393	106	0	0	0	560	499
Jun	374	105	13	7	20	580	479
Jul	367	101	2	9	11	591	468
Aug	352	107	8	1	9	600	459
Sep	352	107	0	0	0	600	459

Table 2—Current mortality of female strobili of slash pine during their development from flowers to mature cones (1972-74) in the McColsky seed orchard near Lake City, FL

Month	Current mortality[a]			
	TK	DK	IK	UK
Dec	0	0	0	0
Jan	0.007	0	0	0.009
Feb	.082	0	0.006	.028
Mar	.001	0	0	.039
Apr	0	0.003	0	.010
May	0	0	0	.003
Jun	0	.040	0	.017
Jul	0	.023	0	.023
Aug	0	.109	0	.017
Sep	0	.015	0	.013
Oct	0	.002	0	.002
Nov	0	.004	0	.009
Dec	0	0	0	.005
Jan	0	.002	0	.007
Feb	0	.002	0	0
Mar	0	0	0	.007
Apr	0	0	0	.007
May	0	0	0	0
Jun	0	.030	0	.002
Jul	0	0	0	.005
Aug	0	.003	0	.019
Sep	0	0	0	0

TK = thrips killed; DK = *Dioryctria* spp. killed; IK = other insect killed; UK = killed by unknown factor.
[a] Proportions of healthy cones killed during the same month by different categories of pests.

Table 3—Current damage and delayed mortality of female strobili of slash pine during their development from flowers to mature cones (1972-74) in the McColsky seed orchard near Lake City, FL

	Current damage[a]				Delayed mortality[b]			
	Thrips	Coneworms	Other insect	Non-insect	Thrips	Coneworms	Other insect	Non-insect
Month	TA	DA	IA	UA	TAK	DAK	IAK	UAK
Dec	0.041	0	0.002	0.013	0	0	0	0
Jan	.071	0	.004	.026	0	0	0	0.214
Feb	.092	0.003	.003	.028	0.588	0	0.333	.297
Mar	.003	.010	.003	.007	.398	0	.286	.863
Apr	.002	.014	.002	0	.038	0.100	.143	.167
May	0	.010	.005	0	.052	.111	0	.300
Jun	0	.002	0	0	.082	.364	.200	0
Jul	0	.002	.004	0	.045	.231	.125	0
Aug	0	.004	0	0	.109	.308	.111	.143
Sep	0	.002	.009	0	0	.182	0	.167
Oct	0	0	.002	.002	.035	0	0	0
Nov	0	.007	.018	0	0	0	.077	0
Dec	0	0	.005	0	0	0	0	0
Jan	0	0	0	0	0	0	0	0
Feb	0	.005	.007	.005	0	0	.045	0
Mar	0	0	0	0	0	.062	0	.375
Apr	0	.002	0	.020	0	.133	0	0
May	0	0	0	0	0	0	0	0
Jun	0	.013	0	.002	.091	.143	0	0
Jul	0	.005	0	.008	.020	.118	.167	.143
Aug	0	.011	.003	.005	0	.059	0	0
Sep	0	0	0	0	0	0	0	0

TA = thrips attack; DA = *Dioryctria* spp. attack; IA = Other insect attack; UA = damage by unknown factor. _AK = previously attacked strobilus that dies; _ = factor responsible, where T = thrips, D = *Dioryctria* spp. I = other insect; U = unknown factor.
[a] Proportion of healthy cones that are damaged (attacked or affected).
[b] Proportion of previously damaged cones that die.

Table 4—Summary of the reported efficacy of acephate and azinphosmethyl pesticides in reducing damage caused by seedworms (*Cydia* spp.) to strobili of slash pine

		Total applications			% Damage			
Chemical	Sprayer	Year[a]	Months	Rate of application	Treated	Check	% Damage reduction	Reference[b]
Acephate	Hydraulic	2	Jan, Feb, May	0.5%, 8 gal/tree	< 0.1	5.0	99	D
Azinphos.	Mistblower	2	Apr, May, Jun	1.0%, 1 gal/tree	9.2	30.0	69	H
Azinphos.	Hydraulic	2	Apr, May, Jun	0.2%, 8 gal/tree			99	F
Azinphos.	Hydraulic	2	Apr, May, Jun	0.2%, 8 gal/tree			98	F

[a] Year of strobilus development during which pesticide applications were made during the study.
[b] Letters refer to the following references: (D) Fatzinger and others 1984; (H) Merkel and Yandle 1965; (F) Merkel 1964.

Table 5—Summary of the reported efficacy of acephate and azinphosmethyl pesticides in reducing damage caused by seed bugs, the southern pine seed bug, ***Leptoglossus corculus*** (Say), and the shield-backed pine seed bug, ***Tetyra bipunctata*** (H.-S.), to strobili of slash pine

Chemical	Sprayer	Total applications		Rate of application	Seed yields			Reference[b]
		Year[a]	Months		% Damage		% Damage reduction	
					Treated	Check		
Acephate	Aerial	1-2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	6.6	16.6	60	E
Acephate	Hydraulic	1-2	Jan, Feb, May	0.5%, 8 gal/tree	4.8	6.2	23	D
Azinphos.	Aerial	1-2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	9.3	16.6	44	E
Azinphos.	Mistblower	1-2	Apr, May, Jul, Aug	1.0%, 1 gal/tree	2.2	6.4	66	G
Azinphos.	Mistblower	1-2	Apr, May, Jun, Jul, Aug	1.0%, 1 gal/tree	1.9	12.0	84	G
Azinphos.	Mistblower	1-2	Jul, Aug	1.0%, 1 gal/tree	3.5	4.8	27	G
Azinphos.	Mistblower	1-2	May, Jun, Jul, Aug	1.0%, 1 gal/tree	6.6	11.4	42	G

[a] Year of strobilus development during which pesticide applications were made during the study.
[b] Letters refer to the following references: (E) Fatzinger and others 1992; (D) Fatzinger and others 1984; (G) Merkel and others 1976.

Table 6—Summary of the reported efficacy of acephate, azinphosmethyl, and ***Bacillus thuringiensis*** pesticides for increasing quality and quantity of slash pine seed

Chemical	Sprayer	Year[a]	Seed Extracted										Pct increase with treatment		Pct decrease with treatment			Reference[b]
			Total		Sound		Empty		Seed bug		Unknown							
			Tx	Ck	Tx	Ck	Tx	Ck	Tx	Ck	Tx	Ck	Tx	Tx	Tx	Tx	Tx	
Acephate[c d]	Aerial	1-2	114.9	107.9	75.3	69.2	17.4	16.1	6.6	16.6	0.7	1.0	6	8	0	60	30	Unpubl.
Acephate[e f]	Hydraulic	1-2	76.0	49.0	72.2	64.2							36	11				D
Azinphos.[c d]	Aerial	1-2	122.5	107.9	73.6	69.2	16.4	16.1	9.3	16.6	.6	1.0	12	6	0	44	40	Unpubl.
Azinphos.[g h]	Mistblower	1-2	78.0	53.0									32					H
Azinphos.[i h]	Mistblower	1-2			88.1	85.1	9.7	8.5						3	0			G
Azinphos.[c h]	Mistblower	1-2			96.0	75.8	2.1	12.2						21	83			G
Azinphos.[j h]	Mistblower	1-2			86.0	83.3	10.5	11.9						3	12			G
Azinphos.[k h]	Mistblower	1-2			82.0	76.3	11.4	12.3						7	7			G
B. thur.[c d]	Aerial	2	105.7	107.9	77.7	69.2	13.2	16.1	8.7	16.6	.3	1.0	0	11	18	48	70	Unpubl.

Tx = treatment; Ck = check.
[a] Year of strobilus development during which pesticide applications were made during the study.
[b] Letters listed refer to the following references: (D) Fatzinger and others 1984; (G) Merkel and others 1976; (H) Merkel and Yandle 1965.
[c] Total applications in April, May, June, July, and August.
[d] Rate of application was 3.0 pounds per acre.
[e] Total applications in January, February, and May.
[f] Rate of application was 0.5%, 8 gallons per tree.
[g] Total applications in April, May, and June.
[h] Rate of application was 1.0%, 1 gallon per tree.
[i] Total applications in April, May, July, and August.
[j] Total applications in July and August.
[k] Total applications in May, June, July, and August.

Table 7—Estimates used as default values in SeedCalc of the efficacy of pesticides for increasing the quantity and quality of seed extracted from cones of slash pine

Factor affecting seed quantity or seed quality	Proportion of pest damage rate expected following applications of pesticides			
	Acephate	Azinphosmethyl	Fenvalerate	*B. thuringensis*
No. seed/cone	1.065	1.135	1.065	1.00
Empty seed	1.00	1.00	1.00	0.18
Seed bug damage	0.60	0.55	0.60	.48
Seedworm damage	.69	.69	.69	1.00
Unknown	.30	.40	.30	.70

Table 8—Summary of the reported efficacy of malathion and acephate pesticides in reducing damage caused by the slash pine flower thrips, *Gnophothrips fuscus* (Morgan), to strobili of slash pine

Chemical	Sprayer	Total applications		Rate of application	% Damage		% Damage reduction	Reference[b]
		Year[a]	Months		Treated	Check		
Malathion	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	17.8	26.1	32	E
Malathion	Aerial	1	Feb, Mar, Apr, May, Jun, Jul	3 lb/ac				
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	4.8	9.2	48	E
Acephate	Aerial	1	Feb, Mar, Apr, May, Jun, Jul	3 lb/ac				
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	6.8	9.2	26	E
Acephate	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	5.6	26.1	79	E
Malathion	Mistblower	1	Jan, Feb	0.75%, 2/3 gal/tree	1.6	9.3	83	B
Malathion	Mistblower	1	Jan, Feb	0.75%, 2/3 gal/tree	4.5	24.6	82	B
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	.4	9.3	96	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	2.1	2.8	25	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	.6	1.0	40	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	.4	29.3	99	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	2.1	18.6	89	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	.8	2.4	67	D
Acephate	Hydraulic	1	Jan, Feb, May	0.5%, 8 gal/tree	1.0	5.7	82	D

[a] Year of strobilus development during which pesticide applications were made during the study.
[b] Letters refer to the following references: (E) Fatzinger and others 1992, (B) DeBarr and Matthews 1971; (D) Fatzinger and others 1984.

Table 9—Summary of the reported efficacy of acephate, azinphosmethyl, *Bacillus thuringiensis*, and fenvalerate pesticides in reducing damage caused by the coneworms, *Dioryctria* spp., to strobili of slash pine

Chemical	Sprayer	Total applications: Year[a]	Total applications: Months	Rate of application	% Damage: Treated	% Damage: Check	% Damage reduction	Reference[b]
Acephate	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	2.3	3.6	36	E
Acephate	Aerial	1	Apr, May, Jun, Jul, Aug	3 lb/ac	1.7	4.1	59	E
Acephate	Aerial	2	Feb, Mar, Apr, May, Jun, Jul	3 lb/ac	9.3	37.5	75	E
Acephate	Aerial	1	Feb, Mar, Apr, May, Jun, Jul					
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	30.9	35.8	14	E
Azinphos.	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	2.7	3.6	25	E
Azinphos.	Aerial	1	Feb, Mar, Apr, May, Jun, Jul					
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	31.7	35.8	11	E
B. thur.	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	16 BIU/ac	1.6	3.6	56	E
B. thur.	Aerial	1	Feb, Mar, Apr, May, Jun, Jul					
		2	Jan, Feb, Apr, May, Jun, Jul	16 BIU/ac	21.1	35.8	41	E
Fenval.	Aerial	1	Apr, May, Jun, Jul, Aug	3 lb/ac	.4	4.1	90	E
Acephate	Mistblower	1	Apr, May, Jun, Jul, Aug	3 lb/ac	1.3	4.1	68	E
Azinphos.	Mistblower	1	Apr, May, Jun	1.0%, 1 gal/tree	1.0	10.5	90	H
Azinphos.	Mistblower	2	Apr, May, Jun	1.0%, 1 gal/tree	8.5	29.5	71	H
Azinphos.	Mistblower	2	Jul, Aug	1.0%, 1 gal/tree	15.6	11.4	0	G
Azinphos.	Mistblower	2	May[c], Jul	1.0%, 1 gal/tree	11.1	32.2	66	G
Azinphos.	Mistblower	2	May, Jun, Jul, Aug	1.0%, 1 gal/tree	6.0	19.5	69	G
Azinphos.	Mistblower	2	Apr, May, Jul, Aug	1.0%, 1 gal/tree	6.0	19.8	70	G
Azinphos.	Mistblower	2	Apr, May, Jun, Jul, Aug	1.0%, 1 gal/tree	5.6	23.4	76	G
Azinphos.	Mistblower	2	Apr, May, Jun, Jul, Aug	1.0%, 1 gal/tree	3.6	25.1	86	G
Fenval.	Mistblower	1	Apr, May, Jun, Jul, Aug	3 lb/ac	.4	4.1	90	E
Acephate	Hydraulic	1	Apr, May, Jun, Jul, Aug	3 lb/ac	0	4.1	100	E
Acephate	Hydraulic	1	Jan, Feb, May	.5%, 8 gal/tree	.4	16.3	98	D
Acephate	Hydraulic	1	Jan, Feb, May	.5%, 8 gal/tree	0	1.2	100	D
Acephate	Hydraulic	1	Jan, Feb, May	.5%, 8 gal/tree	0	7.3	100	D
Acephate	Hydraulic	2	Jan, Feb, May	.5%, 8 gal/tree	0	11.7	100	D
Acephate	Hydraulic	2	Jan, Feb, May	.5%, 8 gal/tree	.5	1.9	74	D
Acephate	Hydraulic	2	Jan, Feb, May	.5%, 8 gal/tree	1.4	1.2	0	D
Acephate	Hydraulic	1-2	Jan, Feb, May	.5%, 8 gal/tree	4.3	10.8	60	D
Acephate	Hydraulic	1-2	Jan, Feb, May	.5%, 8 gal/tree	6.2	21.9	72	D
Acephate	Hydraulic	1-2	Jan, Feb, May	.5%, 8 gal/tree	1.4	4.4	68	D
Acephate	Hydraulic	1-2	Jan, Feb, May	.5%, 8 gal/tree	2.9	5.4	46	D
Azinphos.	Hydraulic	1	Apr, May[d]	.2%, 8 gal/tree			100	F
Azinphos.	Hydraulic	2	Apr, May, Jun	.2%, 8 gal/tree			89	F
Azinphos.	Hydraulic	2	Apr, May, Jun	.2%, 8 gal/tree			95	F
Fenval.	Hydraulic	1	Apr, May, Jun, Jul, Aug	3 lb/ac	0.2	4.1	95	E

[a] Year of strobilus development during which pesticide applications were made during the study.
[b] Letters refer to the following references: (E) Fatzinger and others 1992; (H) Merkel and Yandle 1965; (G) Merkel and others 1976; (D) Fatzinger and others 1984; (F) Merkel 1964.
[c] Applications on May 4 and May 30.
[d] Applications on May 4 and May 16.

Table 10—Summary of the reported efficacy of acephate and azinphosmethyl pesticides in reducing damage by insects other than coneworms, *Dioryctria* spp., or slash pine flower thrips, *Gnophothrips fuscus* (Morgan), to strobili of slash pine (Fatzinger and others 1992)

Chemical	Sprayer	Total applications Year[a]	Months	Rate of application	% Damage Treated	Check	% Damage reduction
Acephate	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	0.1	7.0	99
Acephate	Aerial	1	Feb, Mar, Apr, May, Jun, Jul	3 lb/ac			
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	.1	0.1	0
Azinphos.	Aerial	1	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	.1	7.0	99
Azinphos.	Aerial	1	Feb, Mar, Apr, May, Jun, Jul	3 lb/ac			
		2	Jan, Feb, Apr, May, Jun, Jul	3 lb/ac	0	.1	100

[a] Year of strobilus development during which pesticide applications were made during the study.

Table 11—Summary of the reported efficacy of acephate and azinphosmethyl pesticides applied aerially at a rate of 3 pounds per acre in reducing damage caused by the unknown factors to strobili of slash pine (Fatzinger and others 1992)

Chemical	Total applications Year[a]	Months	% Damage Treated	Check	% Damage reduction
Acephate	1	Jan, Feb, Apr, May, Jun, Jul	31.3	32.6	4
Acephate	1	Feb, Mar, Apr, May, Jun, Jul			
	2	Jan, Feb, Apr, May, Jun, Jul	31.6	35.5	11
Azinphos.	1	Jan, Feb, Apr, May, Jun, Jul	23.5	32.6	28
Azinphos.	1	Feb, Mar, Apr, May, Jun, Jul			
	2	Jan, Feb, Apr, May, Jun, Jul	30.2	35.5	15

[a] Year of strobilus development during which pesticide applications were made during the study.

Table 12—Contents of data file ASAN.SIM taken from program default values for array ASAN(23,4) representing the pesticide fenvalerate where efficacy of fenvalerate is expressed as percentages of reduction in strobilus damage in four categories

Month	Thrips[a]	Coneworms	Other insects	Unknown
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0.95	1.00[b]	0.39[b]
5	0	0.95	1.00	0.39
6	0	0.95	1.00	0.39
7	0	0.95	1.00	0.39
8	0	0.95	1.00	0.39
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	.92[b]	1.00[b]	.21[b]
18	0	.92	1.00	.21
19	0	.92	1.00	.21
20	0	.92	1.00	.21
21	0	.92	1.00	.21
22	0	0	0	0
23	0	0	0	0

[a] Selection of fenvalerate spray also selects malathion spray for thrips.
[b] Assumption—fenvalerate is as effective as azinphosmethyl, therefore, used data for azinphosmethyl.

Table 13—Contents of data file BT.SIM taken from program default values for array BT(23,4) representing *B. thuringensis* where efficacy of BT is expressed as percentages of reduction in strobilus damage in four categories

Month	Thrips[a]	Coneworms	Other insects	Unknown
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0.77[b]	0	0
5	0	.77	0	0
6	0	.77	0	0
7	0	.77	0	0
8	0	.77	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	.57[c]	0	0
17	0	.57	0	0
18	0	.57	0	0
19	0	.57	0	0
20	0	.57	0	0
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0

[a] Selection of BT spray also selects malathion spray for thrips.
[b] Percent R for aerial spray = 0.56; .56 * 1.38 = 0.77.
[c] Percent R for aerial spray = 0.41; .41 * 1.38 = 0.57.

Table 14—Contents of data file CYTH.SIM taken from program default values for array CYTH(23,4) representing the pesticide malathion where efficacy of malathion is expressed as percentages of reduction in strobilus damage in four categories

Month	Thrips	Coneworms	Other insects	Unknown
1	0.71	0	0	0
2	.71	0	0	0
3	.71	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0

Table 15—Contents of data file GUTH.SIM taken from program default values for array GUTH(23,4) representing the pesticide azinphosmethyl where efficacy of azinphosmethyl is expressed as percentages of reduction in strobilus damage in four categories

Month	Thrips[a]	Coneworms	Other insects	Unknown
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	1.00	1.00	0.39[b]
5	0	1.00	1.00	.39
6	0	1.00	1.00	.39
7	0	1.00	1.00	.39
8	0	1.00	1.00	.39
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0.92	1.00	.21[c]
18	0	.92	1.00	.21
19	0	.92	1.00	.21
20	0	.92	1.00	.21
21	0	.92	1.00	.21
22	0	0	0	0
23	0	0	0	0

[a] Selection of azinphosmethyl spray also selects malathion spray for thrips.
[b] Percent R for aerial spray = 0.28; .28 x 1.38 = 0.39.
[c] Percent R for aerial spray = 0.15; .15 x 1.38 = 0.21.

Table 16—Contents of data file ORTH.SIM taken from program default values for array ORTH(23,4) representing the pesticide acephate where efficacy of acephate is expressed as percentages of reduction in strobilus damage in four categories

Month	Thrips	Coneworms	Other insects	Unknown
1	1.00[a]	0	0	0
2	1.00	0	0	0
3	1.00	0	0	0
4	0	1.00	1.00	0.06[b]
5	0	1.00	1.00	.06
6	0	1.00	1.00	.06
7	0	1.00	1.00	.06
8	0	1.00	1.00	.06
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0.87	1.00	.15[c]
17	0	.87	1.00	.15
18	0	.87	1.00	.15
19	0	.87	1.00	.15
20	0	.87	1.00	.15
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0

[a] Average Percent R for aerial spray = 0.79; .79 x 1.38 = 1.09 or 1.00.
[b] Percent R for aerial spray = 0.04; .04 x 1.38 = 0.06.
[c] Percent R for aerial spray = 0.11; .11 x 1.38 = 0.15.

Table 17—Summary of the relative efficacy for three methods of applying pesticides to slash pine trees for control of cone and seed insects

Pest	Chemical	Cone crop	Year	% Control[a] by: Hydraulic	Mistblower	Aerial	Reference[b]
Thrips	Malathion	1st	1985	--	--	32	E
			1967	--	83	--	B
			1967	--	82	--	B
			1984	--	--	48	E
	Acephate	1st	1985	--	--	79	E
			1976	96	--	--	D
			1976	25	--	--	D
			1976	40	--	--	D
			1976	99	--	--	D
			1976	89	--	--	D
			1976	67	--	--	D
			1976	82	--	--	D
			Average	71.14		79	
Coneworms	Azinphos-methyl	1st	1985	--	--	25	E
			1962	--	90	--	H
			1961	100	--	--	F
		2nd	1962	--	71	--	H
			1971	--	0	--	G
			1972	--	66	--	G
			1973	--	69	--	G
			1971	--	70	--	F
			1972	--	76	--	G
			1973	--	86	--	G
			1961	89	--	--	F
			1961	95	--	--	F
			Average	94.67	75.43	25	
Coneworms	Acephate	1st	1985	--	--	36	E
			1983	--	--	59	E
			1983	--	69	--	E
			1983	100	--	--	E
			1976	98	--	--	D
			1976	100	--	--	D
			1976	100	--	--	D
		2nd	1984	--	--	75	E
			1976	100	--	--	D
			1976	74	--	--	D
			1976	0	--	--	D
			Average	95.33	69	56.67	
Seedworms	Azinphos-methyl	2nd	1962	--	69	--	H
			1961	99	--	--	F
			1961	98	--	--	F
			Average	98.5	69	--	
			Overall average[c]	89.7647	75.5455	65.2500	

[a] Percent reduction in damage on sprayed plots.
[b] Letters refer to the following references: (E) Fatzinger and others 1992; (B) DeBarr and Matthews 1971; (D) Fatzinger and others 1984; (H) Merkel and Yandle 1965; (F) Merkel 1964; (G) Merkel and others 1976.
[c] Average over all pests excluding zero data and percentages less than 40 percent.

Appendix I

Example of Output from Economics Module

Company or Organization:	Southern Pine Seed Co.
Orchard Name or Number:	Western Bent Creek
Address:	P.O. Box 1345 Star Route 1 Hatchett Creek, FL 32612
Manager:	John R. Elliottii
Date:	2 March 1994
Pine Species:	Slash pine

Chemical Cost Analysis

Chemical Costs for Plan A	($)	Chemical Costs for Plan B	($)
Acephate	0	Acephate	0
Azinphosmethyl	0	Azinphosmethyl	0
B. thuringiensis	0	*B. thuringiensis*	0
Fenvalerate	0	Fenvalerate	0
Malathion	0	Malathion	0
Additional costs	0	Additional costs	0
Total costs	0	Total costs	0
Cost/germinable seed	0	Cost/germinable seed	0

Yield Analysis

	Plan A		Plan B	
Harvest Yield	Acre	Total	Acre	Total
No. of cones	4,293	42,931	4,923	42,931
Healthy	3,339	33,394	3,339	33,394
Damaged	954	9,537	954	9,537
No. of cones Lost before harvest	5,707	57,069	5,707	57,069
Total lbs. seed	15.53	155.34	15.53	155.34
Total no. seed	225,242	2,252,418	225,242	2,252,418
Extraction Yield				
Total lbs. seed	10.25	102.52	10.25	102.52
Total no. seed	148,660	1,486,596	148,660	1,486,596
Total germinated seed	128,596	1,285,962	128,596	1,285,962

Appendix II

Troubleshooting SeedCalc

This appendix describes the causes and solutions to some common problems experienced when using SeedCalc on different computers.

Emergency exit from SeedCalc:

> The preferred method for leaving the program is to use various exit points provided in the SeedCalc menus. If absolutely necessary, you can also exit SeedCalc by pressing the Control and Break keys simultaneously, then press the Return key.

Once installed, SeedCalc will not run:

> You may be using the wrong version of SeedCalc. SeedCalc is supplied in two versions, one for color monitors and another for monochrome monitors. The software will work with monochrome monitors with text-based graphics cards as well as color monitors with higher resolution graphics. The color version will not operate on monochrome monitors and vice versa. Correct by reinstalling SeedCalc using the version designed for your monitor.

Entering letters at menu results in error messages:

> SeedCalc programs rely on capital letters for input. Attempting to enter lower case letters results in error messages displayed next to the input brackets on the different menus. This can be corrected by turning on (pressing) the Caps Lock (key).

Error message is displayed indicating insufficient memory:

> SeedCalc may be exceeding the RAM available. You may have to remove any RAM drives you have installed.

Cannot install SeedCalc:

> SeedCalc is provided on one high-density diskette (5¼" or 3½"). If your system cannot read high-density diskettes, contact the authors for a low-density diskette version.
>
> To install SeedCalc, you need about 1.2 megabytes of unused space on your hard drive.

Once installed, SeedCalc does not seem to run rapidly enough:

> Although the system will run with older microprocessors (e.g., 8088), faster processors (386, 486 or equivalent) will considerably reduce the time needed to execute a pest management plan.

Follow Pesticide Label Exactly

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Fatzinger, Carl W.; Dixon, Wayne N. 1996. User's guide for SeedCalc: a decision-support system for integrated pest management in slash pine seed orchards. Gen. Tech. Rep. SE-95. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 64 p.

SeedCalc, a decision-support system designed for use on personal computers, evaluates the consequences of different pest management strategies in slash pine (*Pinus elliottii* Engelm. var. *elliottii*) seed orchards. This interactive program allows managers to enter orchard survey data and manipulate pesticides applied, application equipment costs, insect damage rates, strobilus development rates and beginning populations, and pesticide efficacy rates to develop a pest management program that best fits their needs. This guide provides user instructions for SeedCalc, presents screen and printer examples, and describes the structure, assumptions, default values, and flow charts of the system.

Keywords: Cone and seed insects, decision-support system, model, *Pinus elliottii*, slash pine.

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